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TEXTILE RESEARCH JOURNAL

VOL. XVI, No. 11 November, 1946

The Use of Water-Permeability Measurements on Swelling-Type Fabrics*

Francis W. Minor,† Arnold M. Sookne,† J. E. Simpson,‡ and Milton Harris

Research Laboratories of Milton Harris Associates

I. Introduction

The tests used to evaluate water-resistant fabrics are very numerous, but when applied individually, none of them is capable of completely predicting the performance of such materials. Thus, absorption and spray tests evaluate the efficiency of the finish itself, whereas penetration tests are affected by both the fabric and the finish. Of the penetration tests, those which measure the passage of water through a fabric subjected to drops or streams are most realistic, and they therefore may be expected to correlate best with performance in actual rainfall. On the other hand, it has been shown that the hydrostatic pressure test may often lead to absurd conclusions when it is used to evaluate the relative performance of different fabrics in rainfall [1, 2, 3]. Water-permeability measurements are somewhat similar to hydrostatic pressure tests, and it is easy to find examples showing that a reliable prediction of resistance to rainfall cannot be obtained directly from water-permeability tests.

There are, however, a number of rather specialized cases in which the water-permeability test is very useful. The validity of this method for studying fabrics designed for use in water bags, tanks, fire hose, immersion suits, etc., can hardly be questioned, since the test conditions are very similar to the conditions to which the fabric is subjected in use. A more general sphere of application of water-permeability measurements is in the study of fabrics designed for use in rainwear, the effectiveness of which depends in part on the closing of holes or interstices through swelling. Such fabrics have come into prominence in recent years as a result of work at the Shirley Institute [4, 5], and they have been used to some extent in fabrics for Army clothing in this country.

It is the purpose of this paper to show how water-permeability measurements can be used to estimate the relative effectiveness of the swelling mechanism in fabrics of the type described above. A simple apparatus suitable for making such measurements is described, and its application to the study of various cotton and rayon fabrics is illustrated.

II. Method

1. Apparatus and Procedure

A diagram of the apparatus is given in Figure 1. It consists essentially of two lengths of Pyrex industrial piping of 2-inch inside diameter, C and D, which can be joined by means of the flanges, F.

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*This article is the second one from this laboratory of a series dealing with the principal phases of the program of the Office of The Quartermaster General on water-resistant clothing. The first article appeared in the June 17, 1946, issue of the *American Dyestuff Reporter*. The work was performed under the auspices of the Committee on Quartermaster Problems of the National Academy of Sciences.

†Research Associate, Milton Harris Associates.

‡Special Assistant, Research and Development Branch, Office of The Quartermaster General.

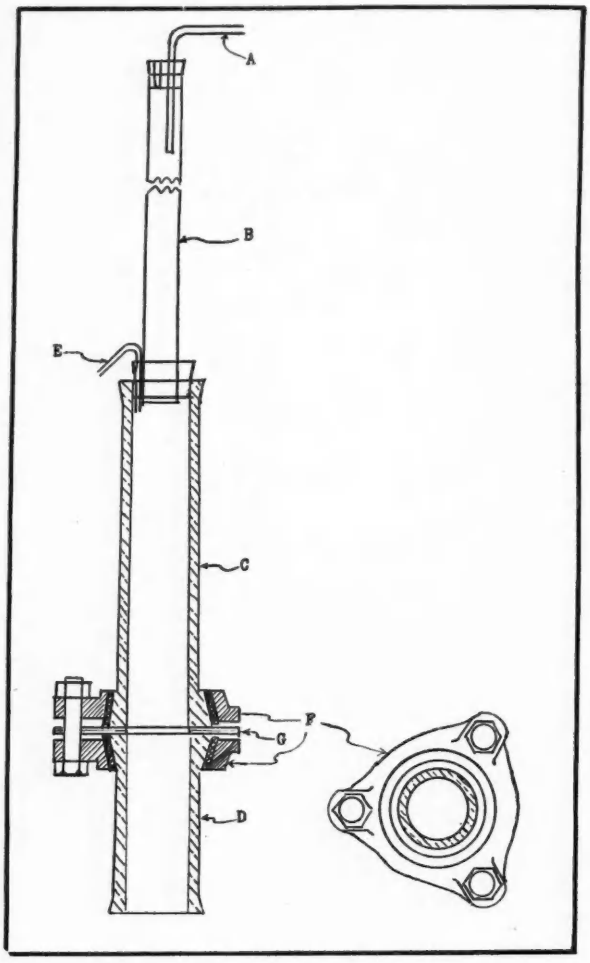

FIG. 1. *Diagram of water-permeability apparatus.*

The glass tube, B, which is about 1 inch in diameter, is of a convenient length for the head of water to be used. Water is led into the apparatus through the inlet, E. A constant head is maintained by means of the tube, A, which is attached to an aspirator. A rubber gasket, G, is used between the tubes C and D.

The sample is placed over a 30-mesh wire screen, which supports it and prevents distortion during the test. The sample, screen, and gasket are clamped between the tubes C and D by means of flanges, and tap water * at 80° ± 2°F is introduced into the inlet E. (The temperature is controlled by passing the water through a coil in a bath maintained at 80°F, and then through a cloth filter to remove any sediment, before it enters the inlet, E.) The sample is then subjected to a predetermined head, and the water leaking through the fabric is collected in a graduate and read as a function of time. The water permeability of a sample is expressed in the units cubic centimeters of water per square centimeter of fabric per minute: $cm^3/cm^2 \times min$. This may be written more simply as cm/min, which represents the speed at which the water moves through the fabric under a given head. Correspondingly, the actual amount of transmitted water has the units cm^3/cm^2, or simply cm.

In the measurements described below, the samples were supported by a wire screen during the test, to avoid the distortion that is produced by high heads. Whether or not a wire screen should be used to support samples during the test depends on the purpose for which the fabric is to be used. Thus, fabrics intended for use in water bags or tanks will be subjected to large hydrostatic heads in use, and should logically be tested without a screen to support them. On the other hand, fabrics intended for use as clothing will not be required to resist such heads in use. It is felt that testing these fabrics without a screen penalizes the lighter fabrics, and unduly rewards some samples for possessing mechanical properties not required in use. In addition, the reproducibility of the data is somewhat better when the samples are supported by the screen.

2. Reliability of the Method

It is difficult to give a numerical estimate of the reproducibility of the test method. In general the variability in the method is apparently very much smaller than that inherent in the test specimens. The method appears to be sensitive to the presence of accidental holes in the test specimen, but this sensitivity must be regarded as an advantage rather than a liability. It is not unusual to obtain results that differ by a factor of 2:1 when duplicate specimens from the same piece of cloth are tested, if the cloth is uneven in weave. It is suggested that a minimum of three specimens be tested, and that a larger number be used if the agreement of the results is not satisfactory.

III. Results and Discussion

1. Rate of Leakage as a Function of Head and Time

The general features of the leakage of a fabric under pressure are shown in Figure 2, which de-

* For practical reasons, filtered tap water was used in all of the experiments described below. A few experiments showed that when distilled water is used, considerably higher water permeabilities are obtained. Possible causes for this effect are given by Bogaty and Carson [6].

scribes the variation in leakage of the same fabric under different hydrostatic heads. In this figure, the cumulative leakage at any given time is plotted against time. The rather tightly woven water-repellent fabric used in the experiment required a head of 51 cm. for leakage to start, and at heads a few centimeters less than this value there was no leakage for several hours. At heads appreciably above 50 cm., leakage occurred, the rate first increasing as the surfaces of the yarns became wetted, and then becoming smaller as the interstices closed because of the swelling of the yarns (see curve at 75 cm. head). At a higher head (100 cm.), leakage was much more rapid and diminished less noticeably as swelling occurred.

The slopes of the curves in Figure 2 at any time represent the rates of leakage at that time. As plotted, the effects of swelling are not very evident, but an examination of the rates of leakage makes these effects clearer. A convenient way to obtain the rates of leakage is to divide the leakage during any time interval by the number of minutes in the interval. Rates obtained in this way from the data in Figure 2 are plotted in Figure 3 against the time at the middle of the interval. As shown by these curves, this fabric reached a maximum rate of water transmission in about 5 minutes (at 100 cm. head) which thereafter fell off rapidly as the measurement was continued. Fabrics of loose weave in general do not show this effect to any marked degree, since the swelling that may occur in such fabrics is insufficient to produce any considerable change in the size of the interstices.

An extreme example of the decline in water permeability as a result of swelling is shown by the results for spun rayon fabrics in Figure 4. The finished fabric, which had been

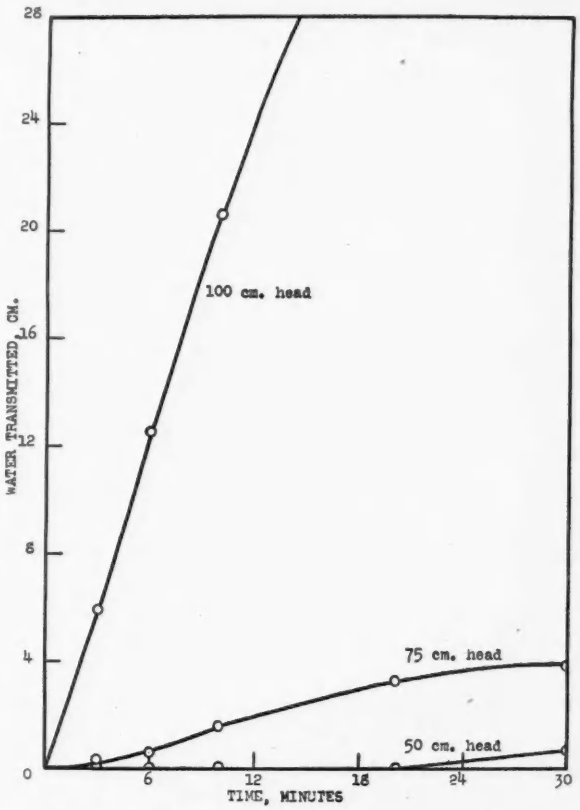

FIG. 2. *Leakage of water through a cotton fabric as a function of time at different heads.*

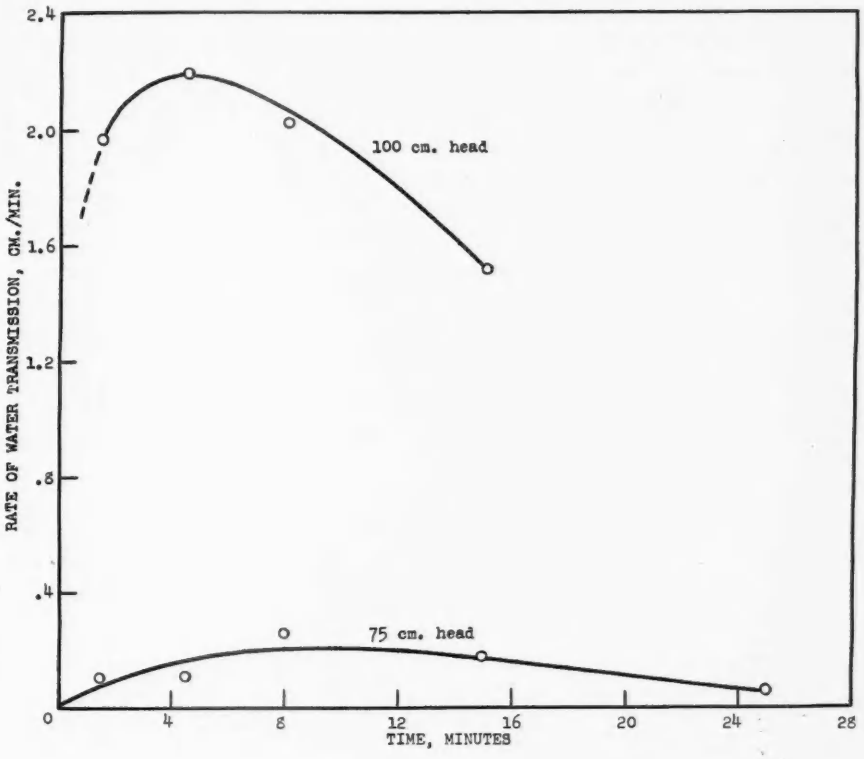

FIG. 3. *Rate of leakage of water through a cotton fabric. These curves are replotted from the data of Figure 2.*

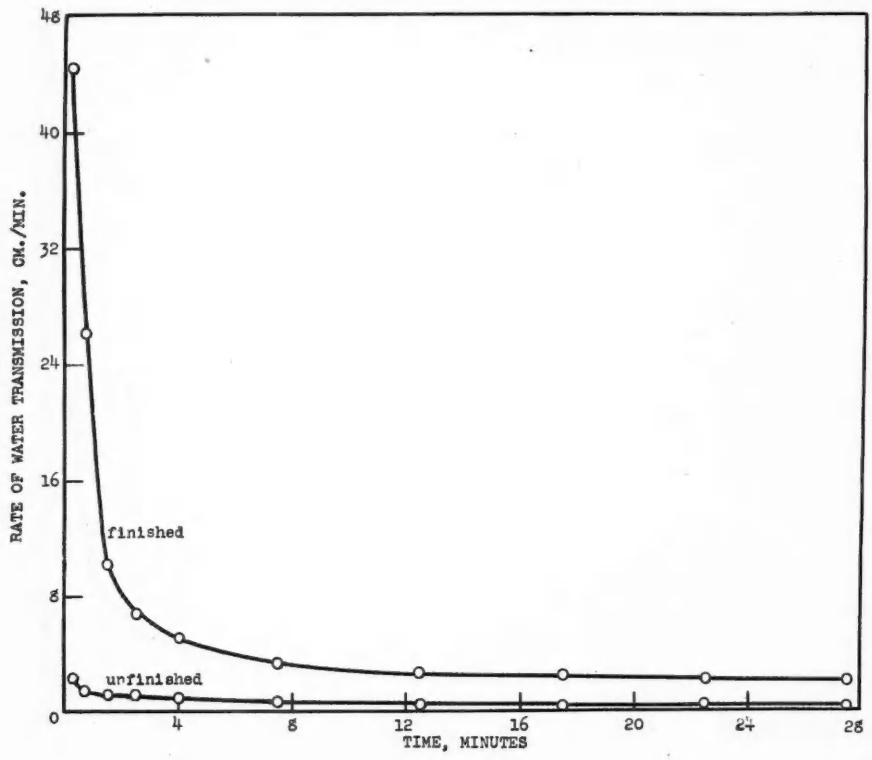

FIG. 4. *Water permeability of a rayon fabric in the repellent and nonrepellent states. Head, 100 cm.*

treated with a water repellent (upper curve), showed an initial relatively high water permeability which markedly decreased during the first few minutes of test, and subsequently slowly declined further. In contrast, the unfinished sample attained a low water permeability within only a few seconds. The rapid swelling of the latter fabric immediately after wetting could be easily observed by viewing it against a light before and after wetting.

2. *Effect of Soaking the Samples Before Test*

As an alternative to measuring the water transmission as a function of time in order to evaluate swelling, it is of interest to compare the water permeability before and after the sample has been subjected to wetting outside of the water-permeability apparatus. The results of a measurement of this type are shown in Figure 5. The tight Oxford fabric was tested under a head of 100 cm. of water before soaking, and after soaking for 24 hours, respectively. In order to remove adhering air bubbles, the soaking was performed in a tall vessel, filled to a depth of 100 cm. As shown by the results in Figure 5, the soaked fabric had a much lower water permeability than the unsoaked sample. A similar effect was shown by the spun rayon fabrics discussed above. Figure 6 shows comparable water-permeability data for the unfinished rayon fabric in the unsoaked state, and after 15 minutes of soaking. The water permeability of the soaked sample was appreciably lower than that of the specimen tested in the initially dry state, but after approximately 15 minutes their permeabilities were equal. Thus, for this fabric, closure of holes that transmit water had almost reached its maximal effect in this time. This is not the case for the finished (water-repellent) rayon fabric, however. As shown by Figure 7, the water-permeability curve for this fabric after 15 minutes of soaking before test is still considerably above that for the nonrepellent sample, and the slope for the former is somewhat greater. It should be noted, however, that there was a tremendous reduction in water permeability of the treated fabric after soaking, as can be seen by comparing the upper curves of Figures 4 and 7.

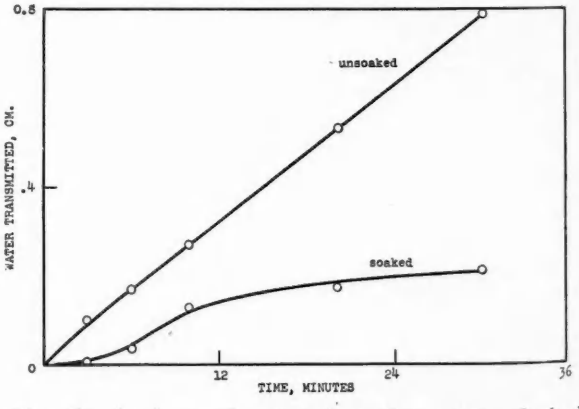

FIG. 5. *Leakage of water through a cotton Oxford fabric under a head of 100 cm. Lower curve, sample soaked 24 hours in water before test. Upper curve, sample tested without preliminary soaking.*

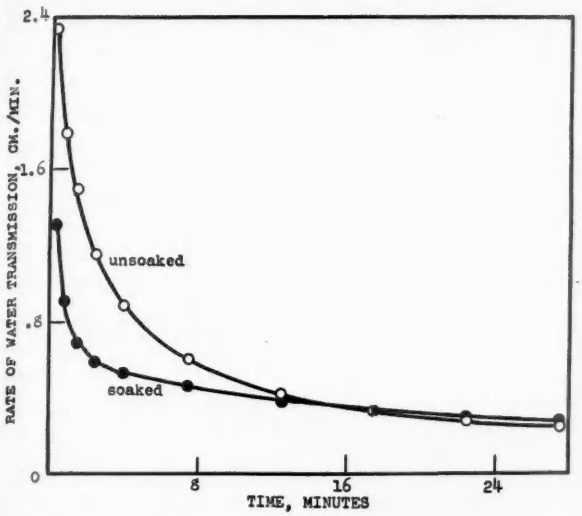

FIG. 6. *Water permeability of a nonrepellent spun rayon fabric under a head of 100 cm. Lower curve, sample soaked 15 minutes in water before test. Upper curve, sample tested without preliminary soaking.*

Examination of the curves presented above reveals that the water permeability never reaches an equilibrium value, but decreases slowly and apparently indefinitely, as the time of measurement is extended. Similar results have been obtained in tests of filter papers [6], which wet immediately. The small but continual diminution of water permeability can hardly be attributed to increased swelling for such materials, and its cause has not been definitely established. While this effect may in some cases be caused by solid particles in the water, some evidence has been advanced to show that it may result from the continued sorption or "plating out" of air in the pores of the filter medium [6]. Regardless of the cause of this diminution of water permeability with time, however, it is apparent that its magnitude is a function of the nature of the water used. Unless adequate quantities of prefiltered distilled water are available, therefore, it is highly desirable to compare the water permeabilities of different fabrics by making the measurements at the same time.

3. *Effect of Finish on Water Permeability and Drop-Penetration Properties*

It has been recognized that in the swelling type of fabric there are two competing mechanisms that affect the penetration of the fabric by rainfall [7]. Thus, the water-repellent finish acts to inhibit penetration by making the surface hydrophobic, but because of its hydrophobicity it also delays closing of

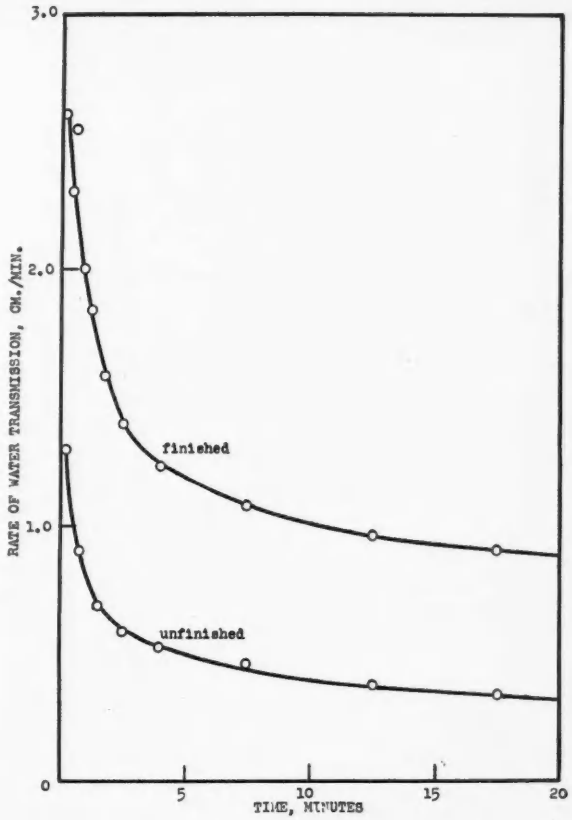

FIG. 7. *Comparison of the water permeability of repellent and nonrepellent rayon fabrics under a head of 100 cm. Samples soaked in water for 15 minutes before test.*

the interstices by swelling. This point is clearly illustrated by the results obtained on samples of spun rayon fabric containing varying amounts of a hydrophobic finish (Table I). However, for water-repellent clothing fabrics, it appears that a balance between these two effects is desirable, for this results in optimum resistance to penetration by falling drops. Sam-

TABLE I. EFFECT OF VARYING AMOUNTS OF FINISH ON THE WATER REPELLENCY OF A SPUN RAYON FABRIC

Sample	Spray Rating	Hard Backing Drop-Penetration Time min.	Water Permeability* cm/min at 100 cm head
A	100	0.7	101
B	90+	2.4	45
C	80−	2.7	24
D	50+	4.1	17
E	0	2.8	2

* The water permeability values are for the first minute of test.

ple A, which contained a large amount of finish, had a high spray rating, and, because its swelling was inhibited by the finish, had a very high water permeability. The interstices in this fabric were relatively large, and the drop-penetration time [3] was consequently quite low. Conversely, sample E, which was unfinished, had a zero spray rating and a very low water permeability. However, even without the help of a hydrophobic finish, this sample resisted the drop-penetration test for 2.8 minutes, approximately four times as long as did sample A, because swelling of the yarns hindered the passage of water through it. In this fabric, however, the constriction of the interstices by this process was not sufficient to entirely stop the flow of water. The highest resistance to penetration by falling drops was shown by sample D, which bore a small amount of hydrophobic finish. The finish helped to resist penetration but allowed sufficient wetting for swelling of the yarns to proceed. In this sample, the closure of the interstices occurred in time to provide additional resistance to penetration while the water-repellent finish was still effective. Thus, sample D bore the optimum finish for this rather special type of fabric. Experience shows, however, that for most tightly woven cotton fabrics, a much better finish (100 spray rating) is required for optimum resistance to falling drops, but that under some circumstances a better performance may result from use of a "poorer" finish.

IV. Conclusion

A simple water-permeability apparatus has been described which yields results that are sensitive to the swelling-shut of interstices in fabrics. While the field of usefulness of this apparatus is somewhat limited, it may be of considerable use in the study of swelling-type fabrics. The results of a study of swelling-type fabrics illustrate the fact that under some circumstances optimum resistance to penetration may be obtained with a so-called "poorer" finish.

Acknowledgment

Grateful acknowledgment is made to Robert S. Bryant and Ruth L. Rasch, who made many of the measurements reported in this paper.

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Electron Micrographs of Cellulose Fibers Ground in Water*

P. H. Hermans †

IN previous papers [1] we have dealt with the physical behavior and the morphology of the grinding products obtained on treating cellulose fibers in a vibrating-ball mill ("Schwingmühle") when in the bone-dry condition. The final product was a powder appearing to be entirely amorphous when examined with x-rays. Electron micrographs of the tiny particles obtained upon its dispersion in water with the aid of ultrasonic waves did not show a very characteristic or interesting structure.

In the present paper some micrographs of fibers ground in the presence of water are offered.‡ The general phenomenon in all cases examined is fibrillar disintegration, which is, however, more pronounced in native than in artificial fibers. The fineness of the fibrils observed ranges down to 0.01 μ or 100 Å. and seems to be limited only by the resolving power of the microscope and the attainable contrasts. No indication of preformed "elementary fibrils" of a certain preferred size was found, contrary to the papers by Hess *et al.* [2] and by Wergin [3], and in conformity with the views of Frey-Wyssling [4] and earlier observations of fiber disintegration by other authors [5, 6]. No distinct particular fine structure of the fibrils could be deduced from the photographs, except in one case of fibers from wood cellulose (sulfite pulp) referred to below.

Figure 1 (a–l) shows ordinary photomicrographs taken with an 8-mm. apochromat (total magnification 65 ×) of ramie, wood pulp, Lilienfeld rayon, and ordinary viscose rayon after various grinding times (the preparations were stained with a dilute iodine-zinc chloride solution and photographed using a dark-green light filter for producing better contrast). It will be seen that fibrillation is more pronounced in the native fibers and less in the artificial ones. Lilienfeld rayon shows more distinct fibrillation than ordinary viscose rayon. (In Figure 1g showing Lilienfeld rayon after 1 hour, two filaments of the original fibers are shown for comparison.) Cotton linters behave very similarly to ramie and wood pulp (no figures reproduced).

The grinding products were also examined in the electron microscope at 90 KV tension,* and photographed on small-size film (24 × 24 mm.). The pictures were then photographically enlarged 5 times in preparing the positive prints shown. The total enlargement is indicated for each picture.

As a rule the most interesting pictures were obtained after a milling time of 1–3 hours. After longer times of grinding the preparations became more and more contaminated with porcelain particles from the mill and ball abrasion.

In Figures 2 to 8 a few of the numerous electron micrographs taken are reproduced. The series referring to the shortest grinding times usually comprise one picture taken at relatively low magnification and several others showing further enlarged details of the former, as indicated by the lettered rectangles.

It seems that on prolonged grinding the fibrillar type of structure becomes less pronounced, the fibrillar fragments of the fibers apparently undergoing other changes than continued fibrillation, as may be seen when comparing Figure 2 (ramie, 3 hours) with Figure 3 (ramie, 12 hours) or Figures 5–7 (wood pulp, 1 hour) with Figure 8 (wood pulp, 12 hours).

As already mentioned, little if any fine structure can be detected inside the fibrils, except in the case of wood pulp fibers (1 hour), where more details can be seen in the pictures at large magnification, as in Figures 5, 6, 7, and particularly in Figures 5A and 6. Although it seems to be undue and speculative to endeavor to interpret these details, it may be of some interest that the fibrils shown in Figure 5A (a

* Communication No. 42 from the Laboratory for Cellulose Research AKU and Affiliated Companies, Utrecht, Netherlands.

† Director of the Institute for Cellulose Research, Utrecht, Netherlands.

‡ Usually about 1 g. of the air-dry fibers was wetted with 100 g. of water.

* The instrument used is of Dutch construction developed in the Laboratory for Technical Physics at the Technical University in Delft in cooperation with Philips, Eindhoven. A description of it will soon appear in *Philips Technisch Tijdschrift.*

[*Continued on page 555*]

FIG. 1. *Ordinary light-micrographs of fibers ground wet (enlargement 65 ×). a, b, c. Ramie ground 1 hour, 2 hours, 12 hours. d, e, f. Wood pulp ground 1 hour, 3 hours, 12 hours. g, h, i. Lilienfeld rayon ground 1 hour, 3 hours, 12 hours. j, k, l. Viscose rayon ground 1 hour, 5 hours, 7 hours.*

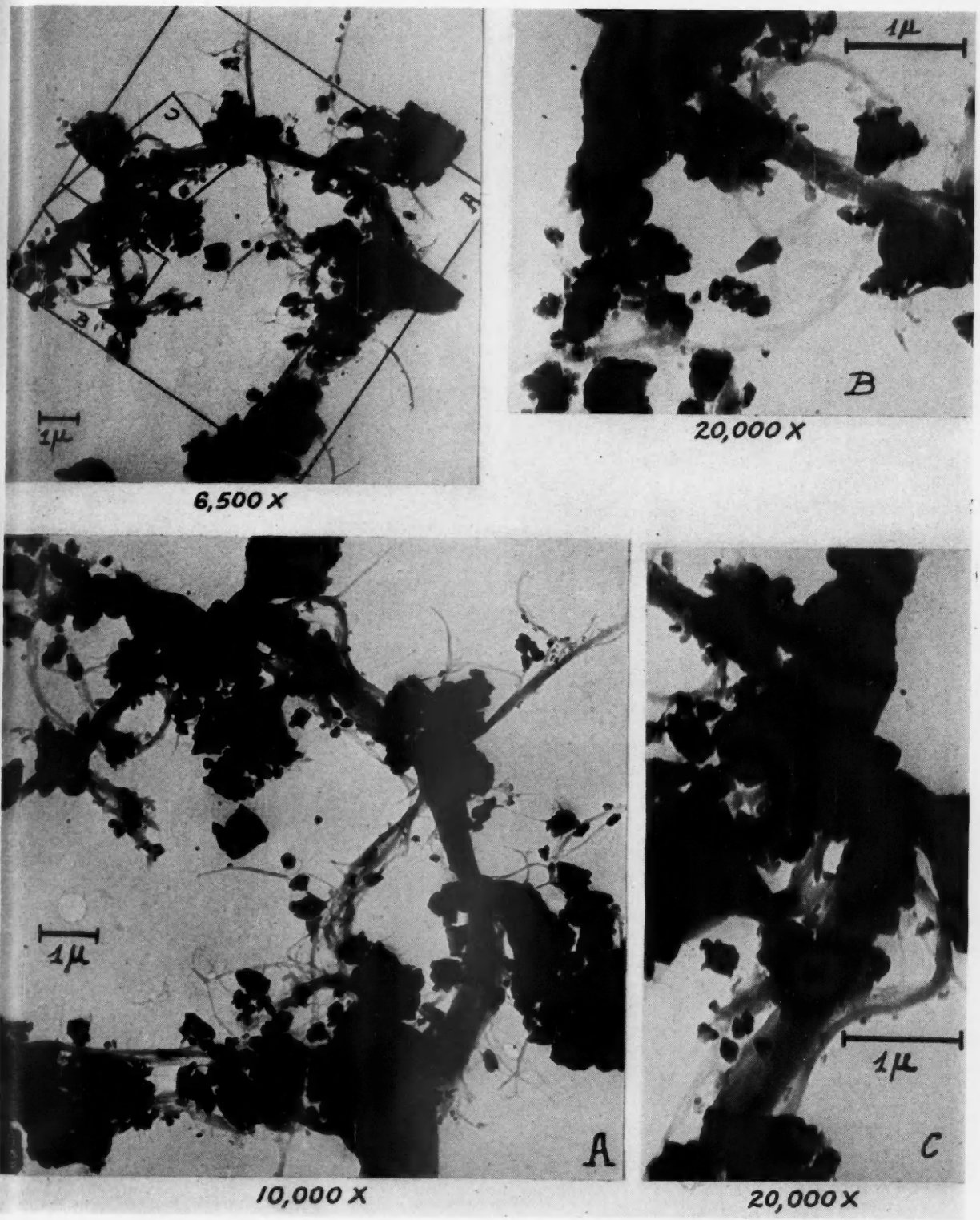


FIG. 2. *Electron micrographs of ramie fibers ground 3 hours.*

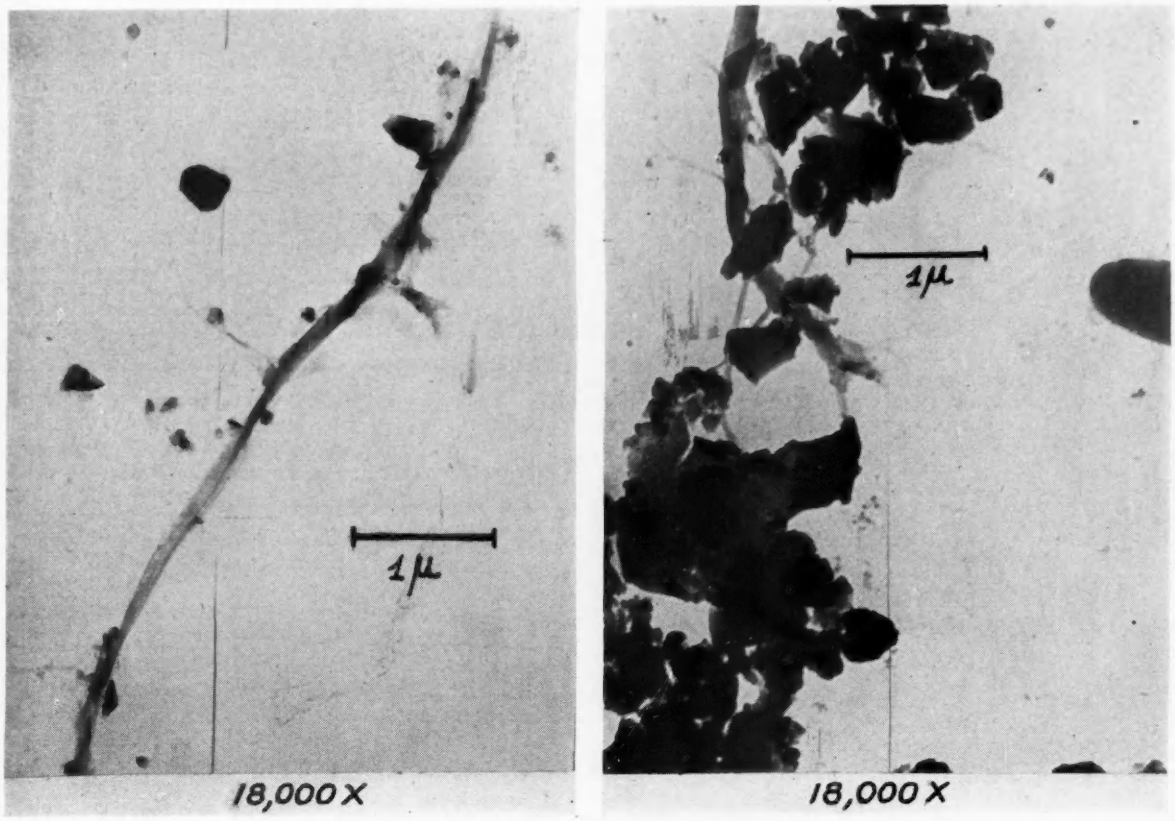


FIG. 3. *Electron micrographs of ramie fibers ground 12 hours.*

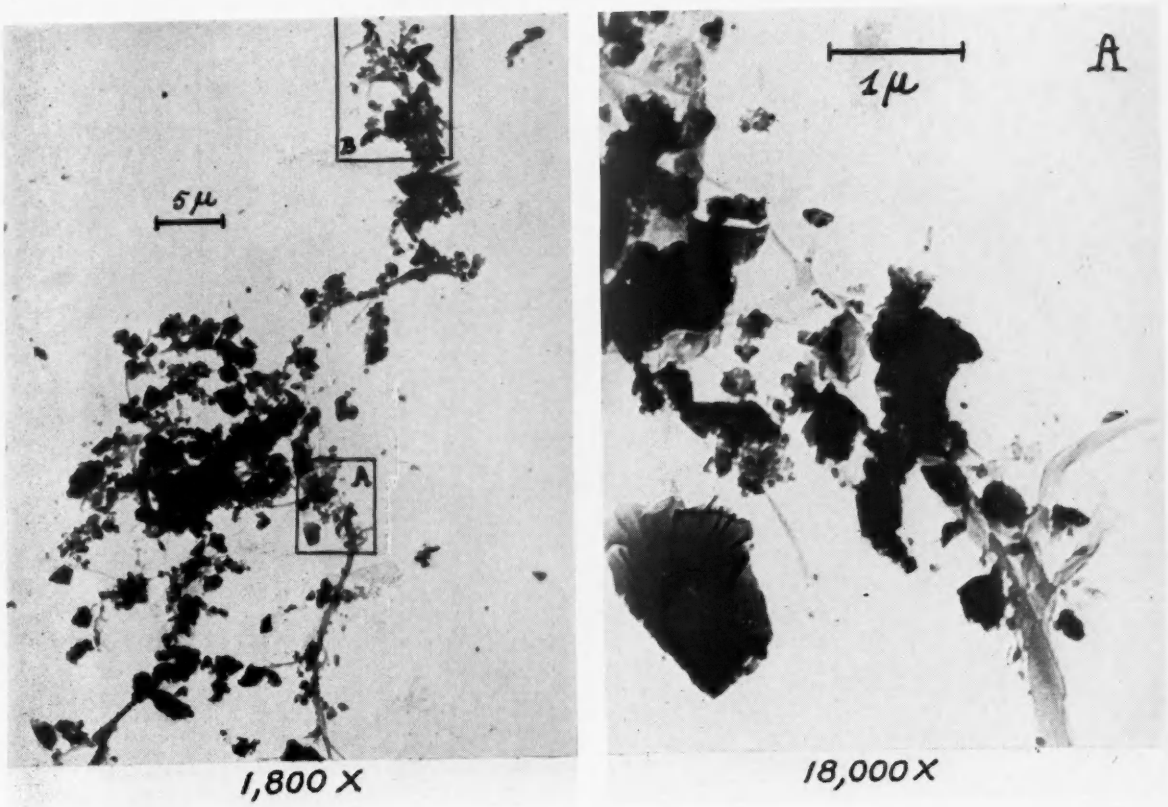


FIG. 4. *Electron micrographs of Lilienfeld rayon ground 3 hours.*

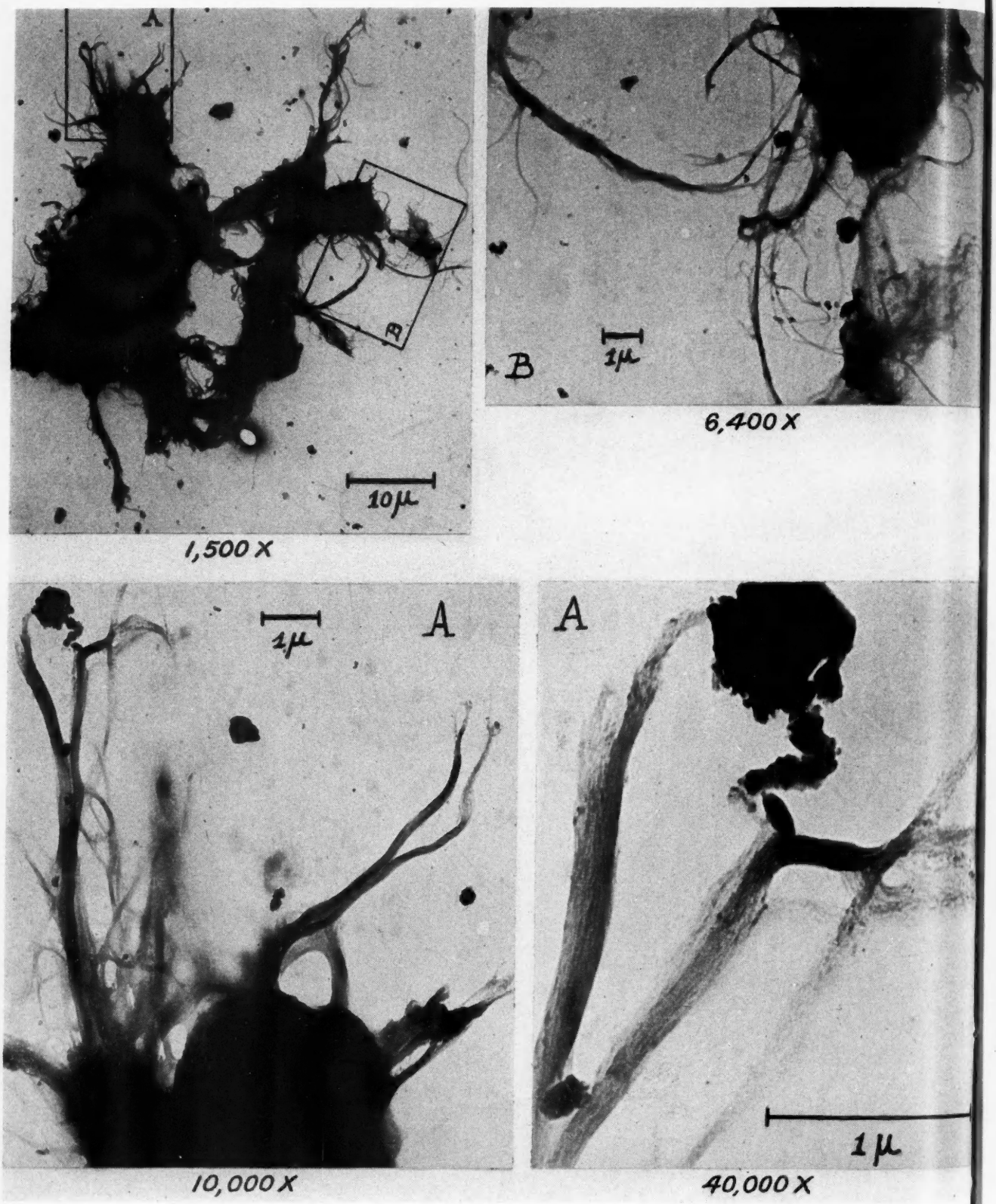


FIG. 5. *Electron micrographs of wood pulp ground 1 hour.*

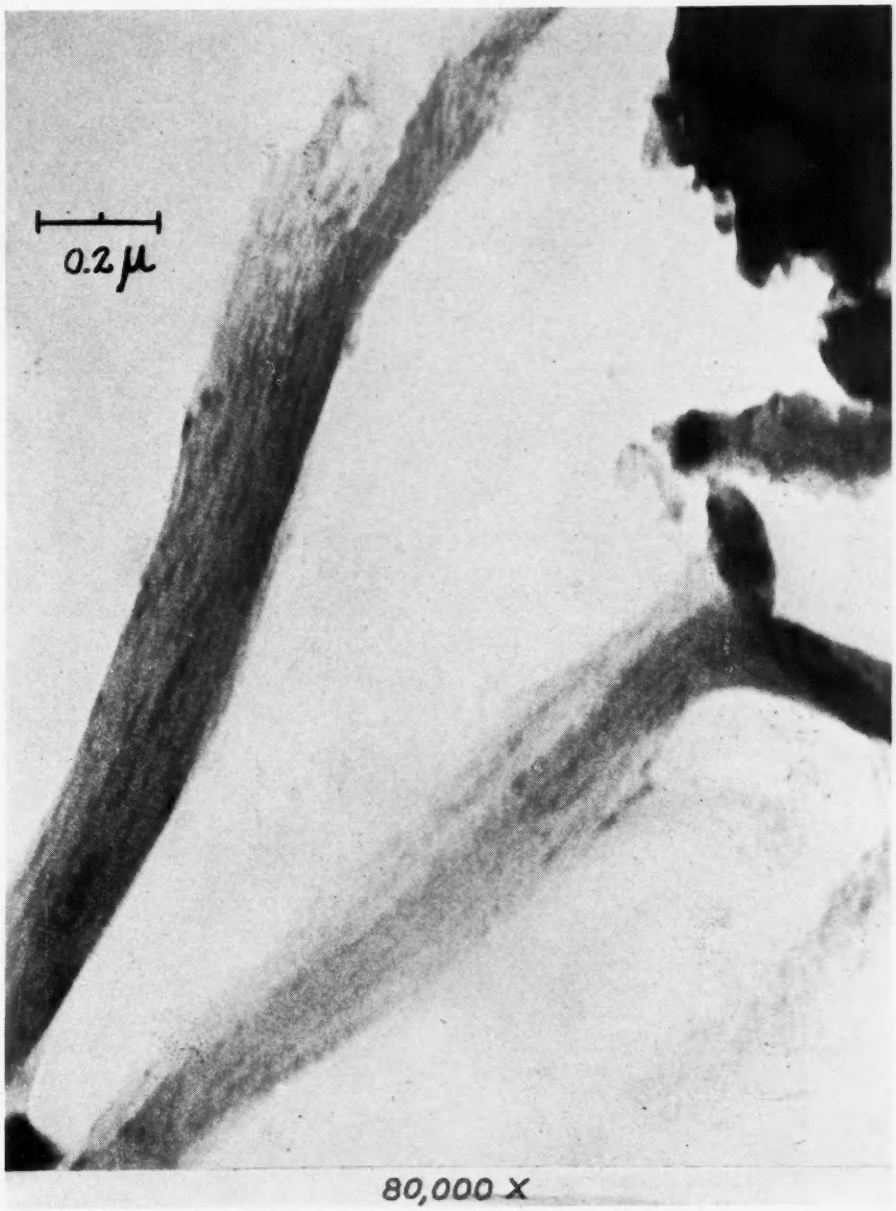
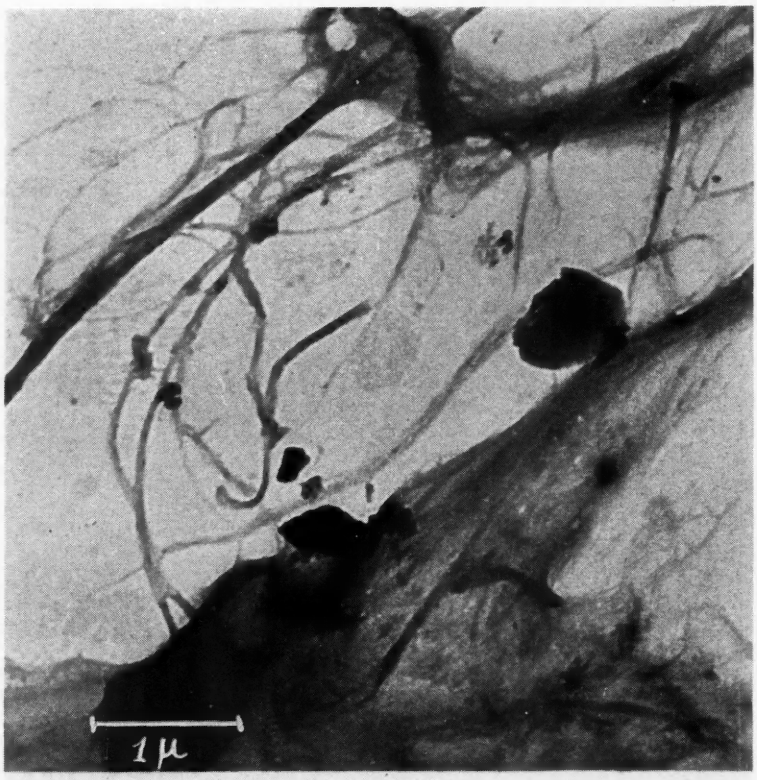


FIG. 6. *Photographic enlargement of Fig. 5A.*



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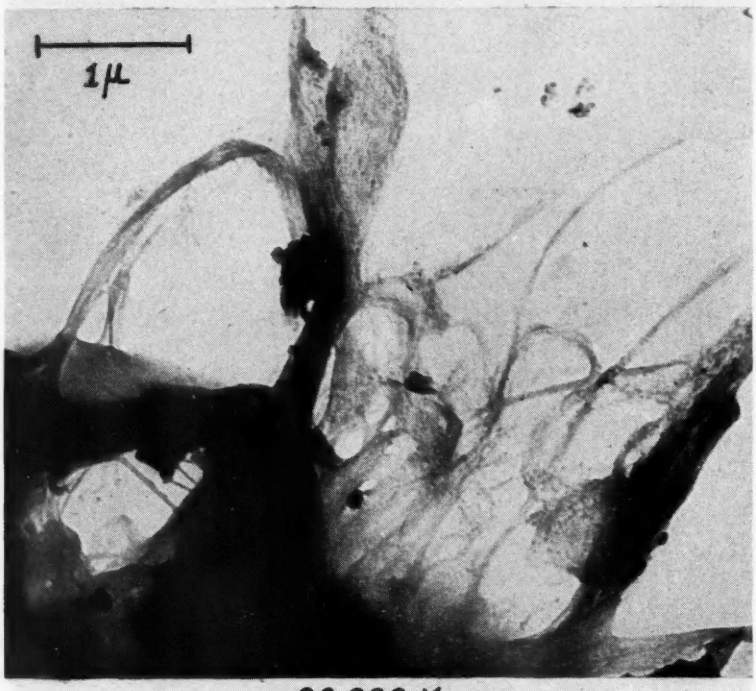

20,000 X

FIG. 7. *Electron micrographs of wood pulp ground 1 hour.*

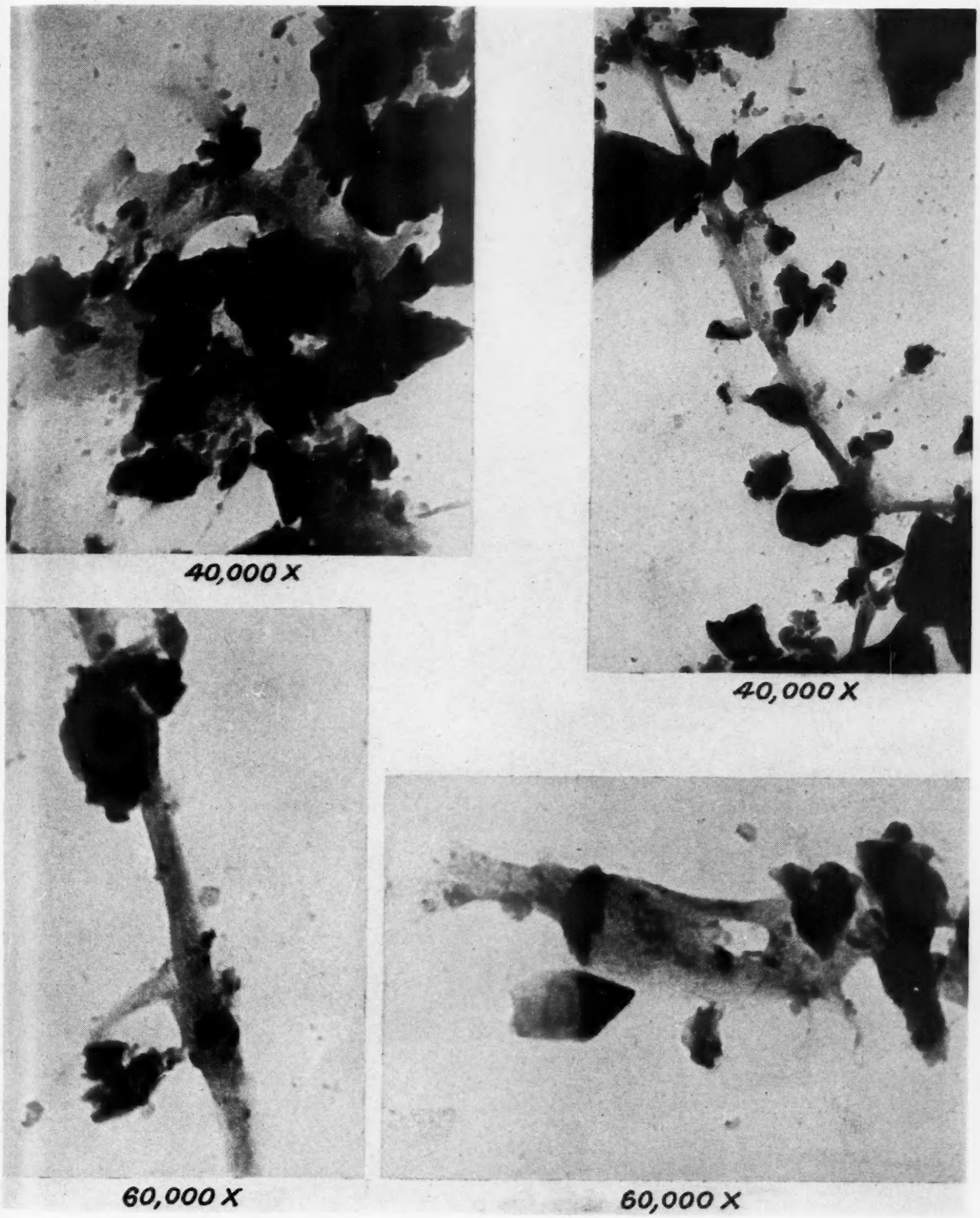

FIG. 8. *Electron micrographs of wood pulp ground 12 hours.*

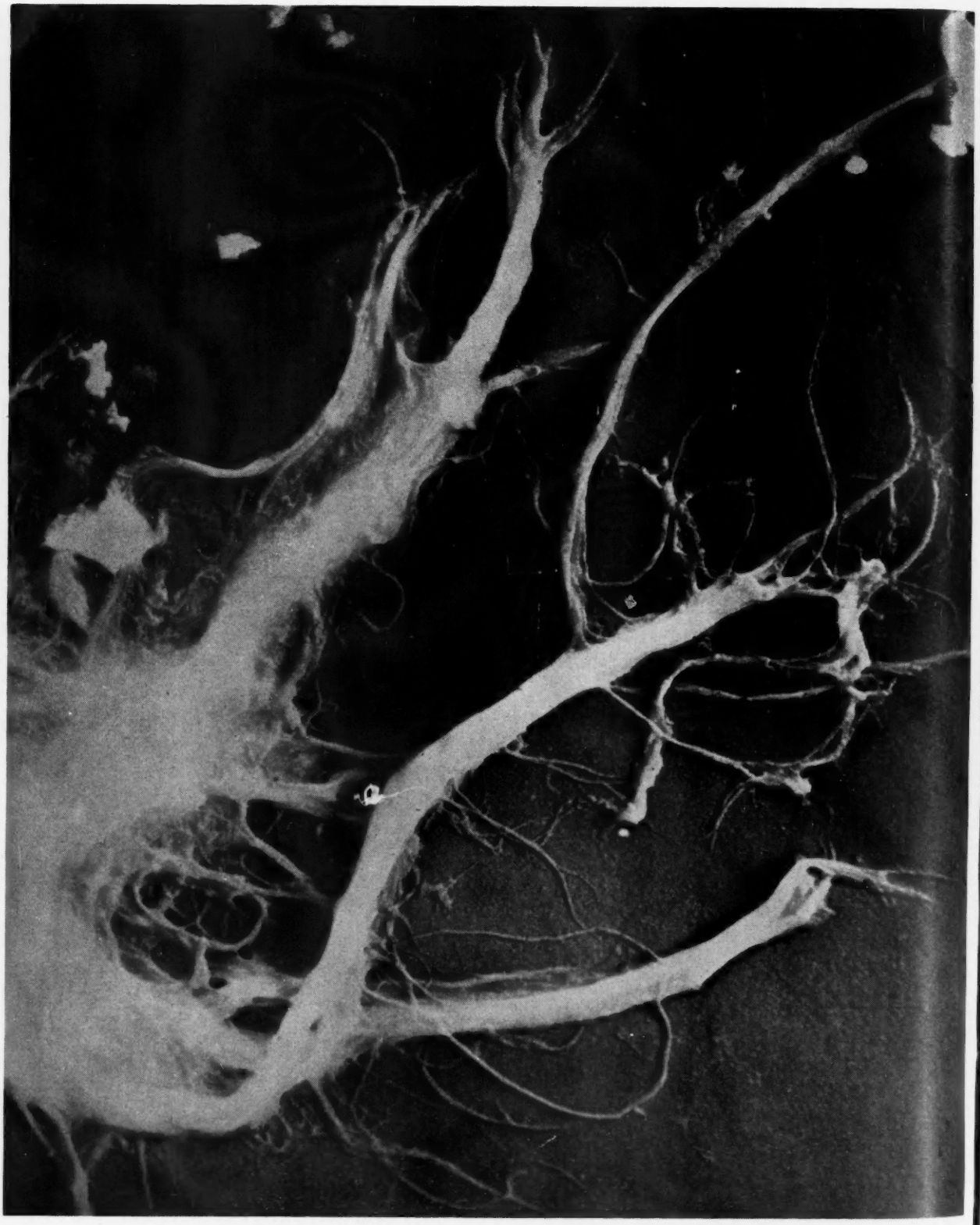

FIG. 9. *Electron micrograph (12,000 ×) of wood pulp ground 1 hour (gold-shadow method).*

[*Continued from page 545*]

further photographic enlargement of which is given in Figure 6) exhibit a structure reminiscent of an orientated "micellar structure" as expected from recent theoretical views. The average width of the tiny dark stripes inside the fibril shown in Figure 6 is in the order of 50 Å. and their mutual lateral distance in the order of 200 Å., figures which are at any rate not in contradiction to these views. It should, however, be taken into consideration that such distinctly periodic structures were not generally found on the other photographs and it must remain undecided whether any importance should be attached to this single case.

In the pictures of the 12-hour preparations no characteristic structures appear. Neither pictures of Lilienfeld rayon ground 12 hours nor of ordinary rayon are reproduced, since they show no details of interest as compared to the pictures already given.

Finally, in Figure 9 a photograph of ground wood pulp (1 hour wet) prepared according to the gold-shadow method is reproduced. The finest fibrils visible here have a thickness of approximately 150 Å. The picture, though very attractive, does not reveal any new features.

Summary

The progressive fibrillar disintegration of cellulose fibers on wet grinding is shown by a series of ordinary and electron micrographs for ramie, wood pulp, Lilienfeld rayon, and ordinary viscose rayon. The disintegration products are all fibrillar, the width of the fibrils observed ranging down to the resolving power of the instrument used. Fibrillation is more pronounced in native than in artificially spun fibers. Only in the case of wood pulp are details of a fine structure inside the finest fibrils more or less distinctly visible. In one case a parallel structure resembling the theoretically expected orientated micellar structure was observed. Here rows of denser, rod-shaped particles about 50 Å. wide and with a mutual lateral distance of 200–250 Å. appear on the photograph. Since this structure appeared only on one of numerous photographs taken, it remains undecided whether any importance may be attached to this observation.

Acknowledgment

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The Possible Contribution of Shape to the Swelling and Moisture-Sorption Behavior of Cotton Fiber at the Saturation Point

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MOISTURE sorption and swelling of cotton fiber are complex phenomena depending in degree upon a considerable number of more or less independent variables which do not lend themselves to control. In the following discussion it is attempted to analyze the effect of a change in one of these variables—namely, the shape—on the moisture behavior of the cotton fiber. Although some quantitative relationships are derived, it must be kept in mind that, because of the assumptions necessary and the number and the complexity of the variables involved, the conclusions drawn can at best be considered only qualitative in nature in specific random cases. They should, however, serve to show in a general way the effect on swelling and related phenomena contributed by fiber shape.

The extent to which a cotton fiber can swell when immersed in water may in some cases be restricted by the cuticle or primary wall [3, 5, 6, 7, 8, 11, 20, 29], which behaves like a membrane around the outside of the fiber. It has been suggested that a mature fiber cannot swell beyond the maximum volume it had as a living, unshrunken cell in the green boll [6, 20], except with strong swelling agents. Since the change in the length of a fiber on swelling is negligible (1 or 2 percent) [9, 10], the change in volume can, as a first approximation, be considered proportional to the change in its cross-sectional area.

Swelling thus presumably involves a change in shape of the fiber so as to cause an increase in the area of the cross section with little or no change in the perimeter. It can be shown mathematically that when the primary wall is distended to its full capacity—that is, its maximum volume—the cross section of the fiber would be circular. A very flat-shaped (immature) fiber with a given perimeter would have a small cross-sectional area and would theoretically swell to many times its original volume before reaching the maximum area. On the other hand, a nearly round fiber could swell very little before reaching this limit, while a perfectly round fiber could not swell at all unless the perimeter of the cross section increased—that is, unless the primary wall stretched.

For the purpose of discussion the first assumption necessary is that the cotton fiber is uniform in cross-sectional area both throughout its length and, for any given sample, from fiber to fiber. The effect of the lumen or of any possible open spaces inside the fiber has been ignored. It has also been assumed that the cellulose within the fiber wall is identical in all cases and that it behaves like a fluid * to the extent that development of a pressure within the primary wall will be prevented by a change in the shape of the cross section. For the sake of consistency the further assumption has been made throughout that the original fiber is oven-dried and therefore has a moisture regain of zero.†

Effect of Shape on Cross-Sectional Area

Figure 1 and Table I illustrate the effect of shape on the cross-sectional area and, therefore, on the volume of a fiber. All of the sections shown have the same perimeter, 27.45 units. Their cross-sectional areas are designated in square units in Table I, column 2. Assuming that the primary wall is nonelastic—that is, that it does not stretch when pressure is built up within the fiber—the maximum cross-sectional area for the given perimeter is that of a circle, 60 square units (see Figure 1, I). From column 2 the maximum possible percentage increase

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* It is actually extruded through breaks in the primary wall in water [3] and from the ends of cut fibers in sodium hydroxide swelling to form "mushroom" ends [5].

† "Moisture regain" as used throughout this paper is defined as the water content in percent on the basis of the bone-dry cotton fiber. Unless otherwise stated, it refers to the fully swollen fiber.

TABLE I. AREAS OF CROSS SECTIONS SHOWN IN FIGURE 1 (PERIMETER IN ALL CASES = 27.45 UNITS)

Cross section No.	*A* Area Sq. units	Percentage swelling to reach circular cross section %	*D* Deformability* %
I	60	0	(−50)
II	59	2	(−47.5)
III	55	9	(−37.5)
IV	53	13	(−32.5)
V	48	25	(−20)
VI	40	50	0
VII	37	62	+9.75
VIII	30	100	25
IX	16	275	60

* Assuming "maximum potential swelling capacity" is 50 percent.

in area—that is, percentage swelling—has been calculated for each of the cross sections shown and is given in column 3.

There is in the literature no quantitative estimate of the maximum capacity of unconfined cotton cellulose to swell in water. Cotton fiber, however, has been said to swell to the extent of about 40 to 50 percent [14, 20, 29] over its bone-dry volume. Actually the figure probably varies slightly from sample to sample since it is a function of many variables, such as percentage of amorphous cellulose, density, and the presence of impurities. Unpublished data recently obtained in this laboratory [24] indicate that the literature values are probably too high. For the purpose of discussion, let us take 50 percent as the "maximum potential swelling capacity" of cotton cellulose. The actual figure chosen does not affect the general conclusions below.

From the data in Table I, column 3, it is apparent that samples I, II, III, IV, and V could show a maximum of only 0, 2, 9, 13, and 25 percent swelling, respectively, whereas samples VI to IX, or any sample having a cross-sectional area of 40 or less than 40 square units, could show the whole of the 50 percent swelling. From Figure 1 and Table I it can be seen that under the conditions mentioned samples I to VI would be expected to take on a circular cross section when immersed in water and allowed to come to equilibrium; sample VII would be expected to change to about the original shape (area) of sample III; and samples VIII and IX would still be fairly flat and have cross-sectional areas of 45 and 24 square units, respectively.

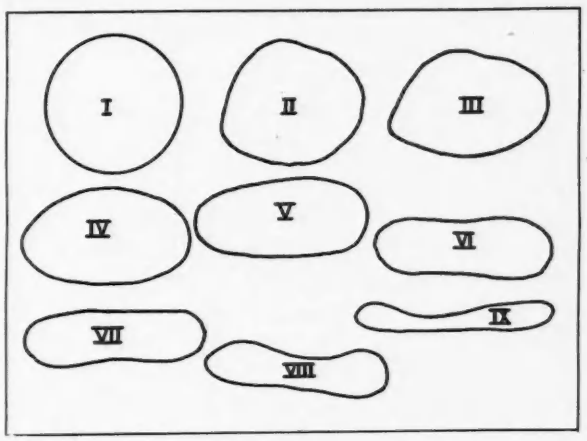

FIG. 1. *Cross sections of nine idealized cotton fibers with the same perimeter (27.45 units).*

Swelling Pressure

The swelling pressure of an elastic gel is a measure of its potential tendency to swell when at equilibrium with saturated water vapor or liquid water. Katz [17, 18] has stated that the following equation, which he derived from the first and second laws of thermodynamics, is applicable to the swelling of elastic gels such as cellulose [28]:

$$P_s = -\frac{RT}{MV_0} \ln \frac{p}{p_0}, \qquad (1)$$

where P_s = the swelling pressure of the gel (for a system in equilibrium with saturated water vapor or liquid water);* M = molecular weight of the liquid (water in the present case) contained in the gel; V_0 = specific volume of this liquid; T = absolute temperature; R = gas constant; p = vapor pressure of the liquid within the gel; and p_0 = vapor pressure of the pure liquid at the temperature in question. The swelling pressure can thus be calculated by this equation from the vapor pressure of the water in the gel.†

When cellulose is swollen to the limit of its "maximum potential swelling capacity" the equilibrium vapor pressure of water (or solvent) would be that

* "It is, however, not correct to say that in a partially swollen body this pressure (swelling pressure) is being exerted. This pressure does not exist until one prevents the body from swelling by mechanical means; previously it does not exist. Likewise, one cannot say that water in a partially swollen body is under this pressure; however, this pressure is the smallest pressure which is sufficient to press water out of the body in question" [17].

† The limitations in the application of this equation for practical calculations of vapor pressures and swelling pressures are discussed by Katz [18, 19].

of pure water (or solvent) at the temperature in question; *i.e.*, $p = p_o$, and the swelling pressure, P_s, would equal zero. When, on the other hand, the cellulose contains only small amounts of moisture—that is, when p is very small—the swelling pressures would be of the order of thousands of atmospheres, a fact taken advantage of by the ancient Egyptians, who split rocks by wetting dry wood which had been forced into holes in the rocks.

It has been shown that wood can be prevented from swelling by applying to the solid phase alone a pressure equal to the swelling pressure [27]. This behavior for restricted swelling is reminiscent of osmotic pressure [19, 26] though swelling cannot be considered to be due to osmosis [3]. In fact, attention has been called [26] to the fact that equation (1) for swelling pressure can be converted to that for osmotic pressure of a solution by letting p represent the vapor pressure of water above the solution.*

An air-dried cotton fiber has a high potential (calculated) value of P_s. When immersed in water it absorbs more and more water and, as it swells, the potential value of P_s decreases progressively until eventually, if the swelling is unrestricted, a value of $P_s = 0$ is reached. This would be expected to happen in the case of sample IX, in Figure 1. If, on the other hand, the extent of the swelling is limited as in the case of sample II, water would be absorbed by the cellulose, and the potential value of P_s would decrease until "stage 1" is reached—that is, the stage at which the fiber is swollen to a circular cross section but without any tension on the primary wall. Then more water would be absorbed, causing a pressure to be built up gradually inside the primary wall and the potential value of P_s would further decrease until "stage 2" is reached at saturation, when the swelling pressure would equal the pressure exerted on the primary wall. At this equilibrium condition the apparent water vapor pressure of the fiber would be that of pure water, but the true or actual water vapor pressure of the unconstrained cellulose having that moisture content would be slightly lower and could theoretically be calculated by solving equation (1) for p.

In the above discussion it has been assumed that the fiber was free to assume a circular cross section. This is a special case. A more general definition of stage 1 and stage 2 should therefore be given as follows:

Stage 1 is that stage in the swelling of a fiber at which the cross section has reached the largest possible area for the given perimeter permitted by the surroundings without any internal pressure on or distention of the primary wall of the fiber.

Stage 2 is the saturation stage at which the fiber is at equilibrium with liquid water. Theoretically this equilibrium should be the same as that with saturated water vapor; actually there is a discrepancy between these two values [19, 25] but this will be ignored in these considerations.

Actually the primary wall is probably elastic. Microscopic and x-ray examination have shown the cotton fiber to be made up essentially of cellulose, mainly in the form of fibrils running almost parallel to the fiber axis and wound with a very thin spiral sheath or helical winding * whose fibrils are in a direction almost transverse to the fiber axis [1, 2]. This outer sheath is called the primary wall of the fiber. The swelling of cellulose is known to be mainly transverse to the fibrils; thus the swelling of the primary wall neither increases the perimeter of the fiber nor contributes appreciably to swelling. If the primary wall is under pressure from within, its distention and the limit of its distention will be a function mainly of the elasticity tangentially along the winding—that is, a function of the percentage elongation of the unwound helix. Judged from the microscopic structure of the primary wall, this maximum elongation might be considered to be roughly the same as that for whole cotton fiber—about 10 percent at 100 percent relative humidity [4, 20].

Using 10 percent as an approximation, the maximum possible change in circumference or perimeter of the fiber by stretching the primary wall without rupture would be 10 percent—for the limiting case in which the winding is exactly transverse to the fiber axis. This would correspond to a maximum increase of 21 percent in cross-sectional area or volume of the fiber.

* Swelling pressure, like osmotic pressure, is equal to the pressure necessary to prevent an increase in volume when in contact with pure water.

* The term "helical" is used in a descriptive sense without rigid geometrical implications. The most recent suggestion that the fibrils form a network or reticular pattern in the primary wall [12, 15, 16, 23] does not affect the validity of the conclusions drawn.

Effect of Shape of Fiber on Swelling Pressure, Percentage Swelling, and Moisture Regain at Saturation Point

Consider the relative swelling behavior of the fibers represented by samples I, II, III, in Figure 1, the primary wall being elastic. On the basis of the original assumptions all these samples have the same potential swelling pressure originally. When immersed in water, they would first swell to a circular cross section without any stretching of the primary wall (stage 1). They would then absorb more water and swell until an equilibrium was reached (stage 2)—that is, until the swelling pressure of the fiber cellulose equaled the pressure distending the primary wall. Obviously at stage 1 the potential swelling pressure of sample I would be greater than that of sample II, and that for sample II would be greater than that for sample III.

It follows that at stage 2 the distending pressure within the primary wall, and therefore the final diameter of the sample, is greater for sample I than for sample II and least for sample III. The total percentage increase in volume due to swelling, on the other hand, will be greater for sample III than for sample II and least for sample I. It also follows that at the saturation (equilibrium) point the moisture regain of the fully swollen sample III will be greater than that for sample II, and II will be greater than I.

In the case of samples VIII and IX, however, as was pointed out above, equilibrium (stage 2) is attained and $P_s = 0$ long before stage 1 can be reached. Thus when equilibrium is reached both of these samples will have swollen by the same percentage and the regain of each will also be identical.

General Relationship for Classification of Moisture-Sorption Behavior When Fiber Is Free to Take Circular Cross Section

For the special "threshold case" at which the value of P_s becomes zero when stage 1 is reached, there is a definite relationship between the perimeter and the cross section of the original fiber. This can be expressed mathematically, as follows:

$$\frac{P^2}{A} = 4\pi\left(1 + \frac{x}{100}\right), \qquad (2)$$

where P = the perimeter of the original cross section; A = its area; and x = the "maximum potential swelling capacity" of the unconfined cellulose, expressed in percent of the original volume. This relation is derived by equating $P^2/4\pi$, the maximum cross section possible for the perimeter P, to the original area increased by x percent.

Equation (2) can be used to classify or predict the type of swelling and water-sorption behavior.* There are obviously two classes into which a fiber might fall, as follows:

Class 1: $P^2/A < 4\pi(1 + x/100)$. For all samples satisfying this condition the swelling is restricted by the primary wall. Thus, as discussed above for samples I, II, III, when immersed in water each of the samples will reach a different equilibrium. The smaller the value of P^2/A, the larger the final swelling pressure will be, and the smaller the moisture regain and the percentage swelling at equilibrium.

"Threshold Case:" $P^2/A = 4\pi(1 + x/100)$. This is exemplified by sample VI (when x equals 50 percent). This is the limiting case of class 2 in which the final cross section of the fiber immersed in water is circular. The final swelling pressure will be zero and the regain and the percentage swelling will also be the same as for class 2.

Class 2: $P^2/A > 4\pi(1 + x/100)$. This class is exemplified by flat fibers such as VIII and IX, Figure 1 and Table I. For all samples satisfying this condition the swelling is unrestricted by the primary wall. Thus when immersed in liquid water all these samples will reach a swelling pressure of zero; they will all have the same moisture regain and exhibit the same percentage of swelling at equilibrium.

When the Fiber Is Prevented from Assuming Normal Circular Cross Section

In the above discussion it has been assumed that the swelling fiber was free to assume a circular cross section. If the fiber is prevented by the surroundings from assuming a circular cross section, the

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* The same kind of mathematical treatment could be applied to the swelling of granules except that here the maximum volume for a given surface would be a sphere. It has been indicated that starch, like cellulose, behaves as an elastic gel [21].

The equation for the "threshold case" corresponding to equation (2) is

$$\frac{S^3}{V} = 6\sqrt{\pi}\left(1 + \frac{x}{100}\right),$$

where S is the total surface of the original granule; V is its total volume; and x is the "maximum potential swelling capacity" of the material inside the granule.

maximum cross-sectional area which it can attain for a given perimeter will be smaller.

Let us consider, for example, the behavior of sample IV, Figure 1, when swollen by immersion in water between two parallel plates 6 units apart. It can be shown mathematically that the maximum cross section to which it can swell without increasing the perimeter will be the sum of the areas of a circle 6 units in diameter and a rectangle 6 units by approximately 4½ units as shown in Figure 2. This

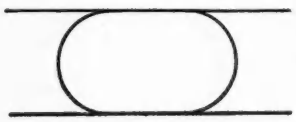

FIG. 2. *Cross section of idealized fiber fully swollen between parallel plates.*

maximum cross-sectional area is approximately 55 square units compared to 60 square units for a circular cross section (sample I, Figure 1) for the same perimeter.

Thus, since the original area of sample IV is 53 square units, stage 1 would be reached with a swelling of $2/53 \times 100$ or 3.8 percent instead of $7/53 \times 100$ or 13.2 percent and at a correspondingly smaller moisture regain and greater swelling pressure. At equilibrium (stage 2) the percentage swelling would be slightly smaller, the moisture regain smaller, and the swelling pressure greater than in the case in which the final shape of the fiber is unrestricted (free to assume a circular cross section).

It is apparent that if the maximum potential swelling capacity (50 percent in the case being considered) is to be realized, the swelling pressure when fully swollen must equal zero and therefore the final cross-sectional area which the fiber is allowed to assume must be taken into account. If the fiber is free to assume a circular cross section, the threshold case (see equation 2) occurs when $P^2/A = 4\pi(1.50)$, or $A = 60/1.50 = 40$ square units, as exemplified by sample VI. The threshold case for the example shown in Figure 2, where the final area was restricted to 55 square units, would have the cross section $A = 55/1.50$ or 36.7 square units. Sample VI when swollen under these restrictions would have a positive swelling pressure at equilibrium so that the primary wall would be distended. Actually when a fiber swells to close up the interstices in a textile fabric, the contours of the fiber would have to take on irregular but indefinable shapes, not circular. Thus to take advantage of the full potential swelling capacity (50 percent) a fiber must be used for which P^2/A is considerably greater than 6π. In fact, the larger P^2/A, the more deformation in contour the fiber can theoretically undergo without P_s exceeding zero.

Let us define deformability, D, of a cotton fiber as the percentage by which the maximum (circular) cross-sectional area for the given perimeter must be reduced in order to equal the original area increased by x percent. That is,

$$\frac{D}{100} = \frac{\frac{P^2}{4\pi} - A\left(1 + \frac{x}{100}\right)}{\frac{P^2}{4\pi}}.$$

In the case of the samples whose cross sections are shown in Figure 1, x being 50 percent, $\frac{D}{100} = \frac{60 - 1.5A}{60}$. The calculated values have been listed in column 4 of Table I. For samples I to V inclusive the deformability is negative. Sample VI is obviously nondeformable; that is, any deformation of the fully swollen fiber will result in a positive value for P_s and a reduction in the percentage of swelling and moisture regain.

It is reasonable to assume that, excluding possible hysteresis effects, the same equilibrium as that represented in Figure 2 could be reached by first allowing the sample to swell to a circular cross section and subsequently, while it is still immersed in water, pressing it between two parallel plates 6 units apart.

A special case of restricted swelling is that of a fiber immersed in water while under tension. The tension would tend to stretch a circular fiber into a longer and narrower cylinder and since the surface of the cylinder would remain essentially constant this would result in a decrease in the final volume. Though the fiber would not be prevented from assuming a circular cross section it would be prevented from assuming its normal cross-sectional area. Thus when immersed in water, a round fiber or a fiber of class 1 under tension would be expected to show lower moisture regain and lower percentage swelling than without tension.

Another special case in the same category should perhaps also be mentioned. The assumption has been made that the cellulose inside the fiber wall behaves like a fluid so that, as it swells, the slightest pressure within the walls will be nullified by a change in shape so that there would be no stresses or strains in the fiber until after a circular cross

section is reached. Actually it seems likely that there is a resistance to change in shape by the cellulose so that at equilibrium sample VI, the threshold case, would not be perfectly round and therefore P_s at stage 2 would be positive instead of zero, the theoretical value.

Swelling of Yarns

The percentage swelling of yarns is not necessarily a measure of the applicability of a cotton fiber for use in "self-sealing" fabrics which depend for their water impermeability upon the closing up of the interstices of the fabric by swelling of the fibers. Consider two yarns made of ideally uniform fibers corresponding to sample VI and sample IX, respectively, and suppose that the vacant space between the fibers is 20 percent of the total volume of the fibers themselves in each case. If the fibers swelled 50 percent the yarn made up of sample VI, if not under tension, would consist of perfectly round fibers and there would therefore still be free spaces between the fibers. Thus, assuming that the free space between the fibers neither increased nor decreased, the area of the cross section of the yarn would increase by roughly 42 percent. In the case of the yarn from sample IX, however, the fibers when swollen 50 percent, possessing high deformability, can shape themselves to contours which fit together so as to close up the free spaces while still in equilibrium with water at $P_s = 0$. Theoretically, the swollen yarn would be expected to have no interstices between the fibers so that a good deal of the swelling would have been taken up by filling these free spaces.* Thus the increase in cross section of the yarn from sample IX would be roughly about 25 percent instead of 42 percent as in the yarn from sample VI. The difference between these two figures, however, is a function of the amount of free space between the fibers in the original yarn and would disappear for loose yarns. It is therefore apparent that the percentage swelling of a yarn when immersed in water is not a measure of its suitability for use in a self-sealing † fabric, nor is it a measure of the swelling capacity of the fibers used in making the yarns. The same can be said of bundles of parallel fibers.

It follows that any method of determination of fiber swelling or self-sealing qualities which involves determining the pressure against the walls of a tubular orifice by, for example, measuring the force necessary to pull out a plug of yarn or parallel fibers is inherently unsound.

It is also indicated, on the other hand, that the rate of seepage of water through a tubular orifice containing a definite volume of dry cotton as a fiber or yarn bundle * is probably a comparatively reliable measure not only of the relative effectiveness of the fiber for use in self-sealing fabrics but also, less accurately, of the percentage of swelling. In the latter case calibration is necessary since the rate of seepage is a complex function of the percentage of swelling. For proper distinction between samples the time factor must be correctly interpreted and the sample must not be prevented by virtue of the swelling—that is, by insufficient contact—from attaining true equilibrium with the liquid water.

The yarn made from sample VI would be expected to shrink slightly more than that made from sample IX when immersed in water, other things being equal. This is apparent from the fact that the fibers would be arranged in a helix because of the twist of the yarn. The increase in cross section of the yarn on swelling would tend to result in an increase in the radius and therefore a decrease in the length of the helix.

Effect of Tension on Swelling and Moisture Regain in Yarns

In the above discussion of the swelling of a yarn under water it was assumed that the yarn was under no appreciable tension but was merely prevented from untwisting. If the yarn is held under tension, the fibers would also be under tension, and if the fully swollen fibers were round or, more generally, if they were swollen beyond stage 1, this tension would cause a decrease in fiber cross section. Tension would also cause a resultant pressure of the fibers against each other; that is, a force perpendicular to the fiber surface which would tend to deform the rounded contour of the fiber shape. Both these fac-

* This would also be true if a small percentage of sample VI were present since the other fibers would conform to their contour.

† It should be noted that at least two other characteristics besides the percent of swelling are involved in the choice of a fiber or yarn for a "self-sealing fabric"—the rate of water sorption and the degree of deformability of the swollen fiber and yarn.

* A method developed by C. F. Goldthwait and H. O. Smith, referred to in *Textile World* **95**, No. 7, 105 (1945), and U. S. Patent 2,352,707. The details of the method are being published.

tors would of course tend to decrease the percentage swelling of the fiber and the yarn, and they would theoretically also cause a decrease in the moisture regain of the fiber since they would both tend to decrease the final volume of the fiber. It follows that, in fibers which swell beyond stage 1, a tight twist and a tight weave would be expected to cause a decrease in both percentage of swelling and of moisture sorption. Peirce [22] mentions the advantage of soft over tight twist for cotton in self-sealing fabrics. It seems possible that this advantage may not hold for flat fibers which tend to close up the yarns and which would also be expected to give more deformable yarns.

Conclusions

From the foregoing a number of predictions and conclusions can be drawn as to the effect contributed by the shape of a cotton fiber on its moisture-sorption behavior. Some of these are enumerated below. In this enumeration "round fibers" designate all fibers which have a circular cross section when at equilibrium with liquid water or, more generally, all fibers which at equilibrium with liquid water have a positive swelling pressure so that the primary wall is under tension.

Unfortunately, the magnitude of the effects cannot be evaluated from existing data. In some cases the effects may not be appreciable under ordinary experimental conditions. Another difficulty in the experimental evaluation of these conclusions is the fact that other variables cannot usually be eliminated, and as a result the effect caused by shape may be augmented, offset, or obscured. It must also be emphasized that some of the basic assumptions lack experimental verification or represent an unattainable ideal, so that the theory and the conclusions might have to be modified accordingly.

If the basic assumptions are sound, the following effects would be expected theoretically when a cotton fiber is immersed in water (or exposed to saturated water vapor):

1. In order that the "maximum potential swelling capacity" of the cellulose may be realized for a cotton fiber of cross-sectional area, A, the value of P^2/A must be equal to or greater than $4\pi(1 + x/100)$, where P is the perimeter of the cross section and x percent is the "maximum potential swelling capacity."

2. Flat (immature) fibers would be expected to show a higher percentage of swelling, a higher moisture regain, and a lower swelling pressure than round fibers. Corroboration of this difference in swelling behavior is suggested by unpublished "seepage" experiments performed in this laboratory [13]. Flat fibers should make better absorbent cotton.

3. Since flat fibers would also be expected to absorb more of a water solution than round fibers, subsequent drying would result in a larger concentration of the solute left in the flat fibers. This fact would theoretically be important in impregnation processes.

4. The greater the value of $P^2/4\pi - A(1 + x/100)$, the greater is the deformability of the fully swollen fiber.

5. Flat fibers, being more deformable than round fibers when fully swollen, would tend to form yarns of greater deformability.

6. Flat fibers would be expected to be better for making "self-sealing" fabrics for at least three reasons: (a) a greater percentage of swelling, (b) a higher degree of deformability, and (c) a higher rate of sorption. The last would be expected to apply for flat fibers since they have a larger surface per unit volume and the moisture would have to diffuse through a shorter distance for complete wetting. Flat fibers would thus fill the interstices of the fabric both more completely and more quickly.

7. A nearly round fiber would show a lower percentage of swelling and a smaller moisture regain if under tension.

8. In cases of fibers where P^2/A is less than $4\pi(1 + x/100)$, restriction by the surroundings from assuming a circular cross section will result in a lower percentage of swelling, a lower moisture regain, and a higher swelling pressure when immersed in water. This would be true of any fiber, whatever its shape, provided its final swollen contour was such that the primary wall was under tension.

9. Breaking of the primary wall of a round cotton fiber by cutting it or by abrasion should increase the percentage swelling and the moisture regain at 100% relative humidity or when immersed in water. Such an increase in swelling has been reported in the literature for water [3] and for 18 percent sodium hydroxide solution [5, 6, 29].

10. Comminution should result in an increase in percentage swelling and in moisture regain for round fibers at the saturation point but not for flat fibers if the method of determination eliminates effects of differences caused by the physical form.

11. In yarns and fabrics of round fibers, tension and

tight twist should tend to decrease the percentage swelling of the fiber and the moisture regain. It seems that a tighter twist might be tolerated in self-sealing fabrics if flat fibers are used, because of their higher degree of deformability.

12. The percentage swelling of a yarn or of a bundle of parallel fibers is not a measure of the swelling of the individual fibers nor of the efficacy of a given yarn or fiber for use in self-sealing fabrics.

13. The "seepage" method of testing yarns or fiber bundles if properly interpreted gives a measure of their applicability in self-sealing fabrics.

14. Other more or less obvious conclusions and applications to problems not only of swelling but also of absorption, dyeing, and shrinkage of yarns and fabrics follow directly from the above analysis. The same principles should also be applicable to other natural fibers having a primary wall.

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Cellulose Studies

VIII. Viscosity and Hydrolytic Degradation of Cellulose in Phosphoric Acid Solution *

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Contribution from The Textile Foundation and the Frick Chemical Laboratory at Princeton University

IT has been generally accepted that there is a relationship between the chain length and the viscosity of a cellulose molecule in an appropriate solvent. Early experiments suggesting this relation were carried out by Berl and Klaye [1], Ost [2], Gibson [3], and others.

Staudinger [4] postulated a quantitative expression relating molecular weight and viscosity. He observed that the viscosities of a number of solutions of synthetic chain polymers apparently were directly proportional to the molecular weight of the dissolved material. He arrived at a suitable equation (1) to fit these results,

$$\frac{\eta_{sp}}{c} = K_m M, \tag{1}$$

where c is the concentration; η_{sp} is the specific viscosity, *i.e.*, the increase in relative viscosity, $\eta_{rel} - 1$, caused by the solute; M is the molecular weight of the dissolved polymer; and K_m an empirical constant. This K_m is determined by independent physicochemical means such as by the use of osmotic pressure measurements.

In its application to cellulose solutions, Staudinger's "viscosity law" has been much criticized by numerous investigators. It has been pointed out that the law is empirical and is based on a number of assumptions which are not necessarily true. Some of these assumptions are that the cellulose is completely "dispersed" in solution, that the "molecules" maintain a rigid, rod-shaped structure in solution, and that η_{sp}/c is independent of the concentration. McBain and McBain [5] have shown that the viscosity of a cellulose solution is far greater than one would expect for the size and shape of a cellulose molecule. This they interpret as caused by such structural features as entanglement and local adherence of the molecules.

Kraemer [6] has modified Staudinger's law by extrapolating the viscosity to zero concentration. The extrapolated viscosity is termed intrinsic viscosity,

$$[\eta] = \left(\frac{\log_e \eta_{rel}}{c}\right)_{c \to 0}, \tag{2}$$

where η_{rel} is the viscosity of the solution relative to that of the solvent, and c the concentration in grams per 100 ml. of solution. From this he expresses the degree of polymerization as

$$\text{D.P.} = K\ [\eta], \tag{3}$$

where K is an empirical constant which is determined by calculating D.P. from the ultracentrifugal molecular weight of cuprammonium cellulose.

Measuring the viscosity of cellulose solutions has been much used for following the degradation of cellulose during many reactions. Although this method measures weight-average molecular weight rather than number-average molecular weight, it was found to agree roughly with end-group measurements and with other means of determining molecular size.

A. The Initial Degradation of Cellulose: Hydrolysis of Semiacetal Bonds

In the previous article of this series [7] a new concept of cellulose structure was presented for the explanation of the initial degradation of cellulose by dilute acids. Titration of end-groups by potassium permanganate showed that "hydrocellulose," the initial product of degradation, contained fewer reducing groups than the material from which it was prepared. This was in direct conflict with the results obtained by older methods, which had apparently demonstrated that the reducing power was greater after acid treatment—that is, the molecular weight was less, owing

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to the hydrolysis of the 1,4-glycosidic bonds within the cellulose molecules.

Viscosity experiments supposedly have confirmed this mechanism, since "hydrocelluloses" have shown lower viscosities and thus, presumably, lower molecular weights.

Our experimental results led us to postulate a fundamentally different mechanism. Briefly reviewed, it consists of the following: (1) Hydrolysis of 1,4-glycosidic bonds is not responsible for the properties of hydrocellulose—namely, its powdery, brittle nature and greater chemical reactivity. (2) Instead, the acidic medium causes the rupture of semiacetal bonds which join primary chain molecules, the true "cellulose molecules," into secondary chain molecules. Besides these semiacetal linkages, hydrogen bonds holding the secondary chain molecules together in lateral direction are also split by acidic reagents. (3) The lowering of end-group content derives from the smallest reducing molecules in the fiber being selectively freed by hydrolysis of their semiacetal bonds and washed into solution. This washed-away material was characterized experimentally. (4) The properities of a hydrocellulose then result from rupture of the semiacetal bonds and part of the hydrogen bonds which hold the secondary chain molecules into a fiber rather than from the hydrolytic scission of the primary chain molecules themselves.

Clearly then, the above picture is contrary to interpretation heretofore offered of viscosity measurements. It was, therefore, felt necessary to investigate viscosity phenomena in order to resolve this conflict.

A number of solvents have been used for viscosity measurements. One of the most important is cuprammonium solution. It is difficult to use in practice because of its high alkalinity, a factor which readily causes degradation of the dissolved cellulose through air oxidation. A possible mechanism of the oxidative degradation of cellulose in alkaline media was presented in Part I of this series [8] and it will be further discussed in a forthcoming publication.

Since we wished to study the effect of acidic media on the viscosity of cellulose, we selected 85 percent phosphoric acid as our solvent. Its use avoids the complication of oxidative degradation, and thus changes which do occur cannot be attributed to such a reaction. According to af Ekenstam [9] cellulose solutions in phosphoric acid are "eminently suitable" for molecular weight determination because cellulose remains unchanged "for hours" in this medium. Staudinger and Daumiller [10] give a value for K_m of 18.0×10^{-4} at 20°C, whereas af Ekenstam's value for the same temperature is 12.4×10^{-4}. In our calculations we have used the former authors' figure.

Surgical cotton and a hydrocellulose were employed for our experiments. The latter was prepared by treating surgical cotton with 5*N* sulfuric acid for 3 hours at 60°C. The samples were thoroughly washed and dried. Three samples of each were weighed out: 0.05, 0.15, and 0.25 gram. These were each dissolved in 100 ml. of 85 percent phosphoric acid in about 40 minutes by the aid of a mechanical shaker. Each solution was then rapidly passed through a sintered glass filter to remove insoluble particles. The weight of this residue was subsequently determined in order to supply any necessary corrective factor to the actual weight of cellulose in solution. It was desired to follow the viscosities of these solutions as they changed with time.

The viscometers were of the Ostwald type as modified by Fenske. These were kept in a constant temperature bath of 20°C ± 0.1°. Readings were taken at frequent time intervals. The results are summarized in Tables I and II. Figure 1 shows the change with time of the specific viscosities of surgical cotton and hydrocellulose solutions of comparable concentrations, and in Figures 2 and 3 the $2.3/c \log \eta_{rel}$ values for the cotton and hydrocellulose solutions, respectively, are plotted versus concentrations to give the intrinsic viscosities. Figure 4 shows the changes with time of the intrinsic viscosities of the same materials. First, it can be observed that in both Figures 1 and 4 the viscosity of the cotton solution rapidly diminishes, reaching a very low value after a comparatively short time. Second, the value of the hydrocellulose viscosity sinks to approximately the same level. The difference between the two is most apparent at the beginning of the experiment, where the cotton has initially a very high value, while the hydrocellulose viscosity is very low by comparison.

The type of curve obtained in the case of cotton has been observed before. Stamm and Cohen [11] have done a careful investigation of this phenomenon. However, they interpreted their curves as measures of rate of hydrolysis of 1,4-glycosidic bonds. On first glance, the above results would seem to fit very nicely with such a picture. The curves of both substances would then be a measure of the rate of hydrolysis of these glycosidic bonds and, in addition, a measure of molecular size at any given moment. Thus it would be probable that the content of the

TABLE I. VISCOSITY MEASUREMENTS. COTTON. 20°C ± 0.1°

Weights of samples: A—0.020 g.
B—0.090 g.
C—0.174 g.
Solvent: 85 percent phosphoric acid

Time (hrs.)	Flow time (secs.)			η_{rel}			η_{sp}			$\frac{2.3}{c}\log\eta_{rel}$			$[\eta]_{c\to 0}$
	A	B	C	A	B	C	A	B	C	A	B	C	
0	28.0*	27.9*	29.1*	—	—	—	—	—	—	—	—	—	—
1	36.4	80.4	170.5	1.30	2.88	5.86	0.30	1.88	4.86	13.1	11.7	10.1	13.4
2	35.3	71.8	147.8	1.26	2.57	5.08	0.26	1.57	4.08	11.5	10.5	9.3	11.8
3	34.2	64.8	126.1	1.22	2.32	4.33	0.22	1.32	3.33	9.9	9.4	8.4	10.2
5	33.0	57.3	102.3	1.18	2.05	3.52	0.18	1.05	2.52	8.3	8.0	7.2	8.6
10	31.9	48.3	75.0	1.14	1.73	2.58	0.14	0.73	1.58	6.6	6.1	5.5	6.7
18	30.8	43.0	59.0	1.10	1.54	2.03	0.10	0.54	1.03	4.7	4.8	4.1	4.7
23	30.2	38.4	53.8	1.08	1.37	1.85	0.08	0.37	0.85	3.8	3.5	3.5	3.8
28	29.6	36.3	50.2	1.06	1.30	1.73	0.06	0.30	0.73	2.9	2.9	3.1	2.8
47	29.4	33.4	43.6	1.05	1.23	1.50	0.05	0.23	0.50	2.4	2.3	2.3	2.4
72	28.8	31.2	36.4	1.03	1.12	1.25	0.03	0.12	0.25	1.4	1.25	1.3	1.4
100	28.5	29.6	32.6	1.02	1.06	1.12	0.02	0.06	0.12	1.03	0.64	0.65	0.80
120	28.2	29.3	31.4	1.01	1.05	1.08	0.01	0.05	0.08	0.46	0.54	0.44	0.60
144	28.2	28.5	30.5	1.01	1.02	1.05	0.01	0.02	0.05	0.46	0.23	0.28	0.48

* Flow time of solvent.

solution would be largely glucose or other small-sized molecules after the reaction had proceeded to the point of very low viscosity values. Furthermore, the difference in the initial viscosities of the two substances would be a measure of the amount of hydrolysis of the 1,4-glycosidic bonds suffered by cotton during the preparation of the hydrocellulose. Using Staudinger's equation, the apparent molecular weights would be:

		Mol. wt.	D.P.
Cotton initially	≦	250,000	1,500
Hydrocellulose initially	≦	40,000	245
Both after 140 hours	≦	2,600	16

It is evident from Figures 1 and 4 that if the curves were followed for a longer period of time the molecular weight would apparently sink lower and lower until at last the molecular weight of glucose was reached. This is, of course, beyond the range of the viscosity method, but it seems to be the reasonable conclusion. In fact, af Ekenstam [9] postulated that the molecular weight of the final hydrolysis product dissolved in phosphoric acid is 240.

However, these curves can be interpreted in quite another way, which fits in with our explanations and is consistent with further experimental data which will be presented later in this paper.

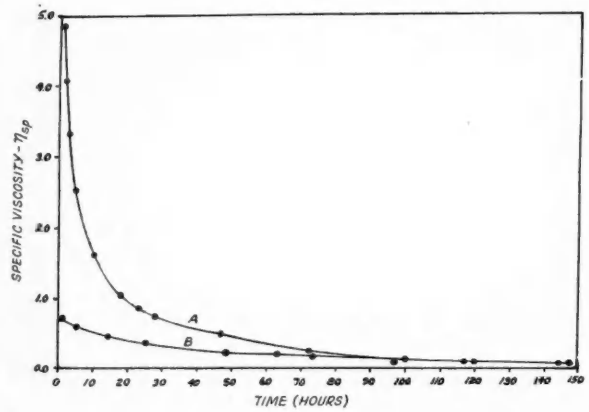

FIG. 1. *Specific viscosity versus time. A—0.174 g. cotton in 100 ml. 85 percent phosphoric acid. B—0.150 g. hydrocellulose in 100 ml. 85 percent phosphoric acid.*

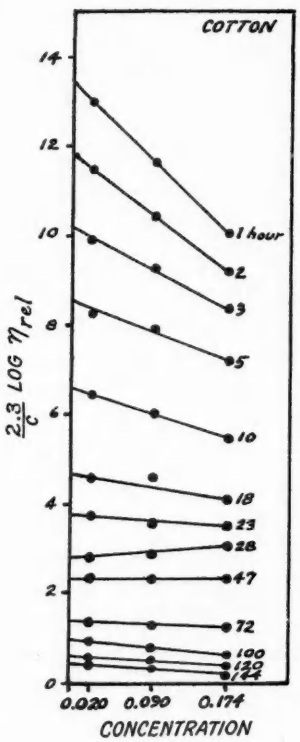

FIG. 2. $\frac{2.3}{c}\log\eta_{rel}$ *versus concentration of cotton in 100 ml. 85 percent phosphoric acid.*

TABLE II. VISCOSITY MEASUREMENTS. HYDROCELLULOSE. 20°C ± 0.1°

Weights of samples: A—0.05 g.
B—0.15 g.
C—0.25 g.
Solvent: 85 percent phosphoric acid

Time (hrs.)	Flow time (secs.)			η_{rel}			η_{sp}			$\frac{2.3}{c}\log\eta_{rel}$			$[\eta]_{c\to 0}$
	A	B	C	A	B	C	A	B	C	A	B	C	
1	33.0	46.3	62.3	1.18	1.66	2.14	0.18	0.66	1.14	3.21	3.16	3.05	3.25
5	32.4	43.2	56.1	1.16	1.55	1.93	0.16	0.55	0.93	2.97	2.74	2.64	3.05
14	31.9	40.6	50.5	1.14	1.46	1.74	0.14	0.46	0.74	2.42	2.37	2.22	2.50
24	31.1	37.8	46.0	1.11	1.36	1.58	0.11	0.36	0.58	2.08	1.92	1.83	2.10
48	30.0	34.0	39.3	1.07	1.22	1.35	0.07	0.22	0.35	1.50	1.24	1.20	1.50
63	29.4	32.1	36.4	1.05	1.15	1.25	0.05	0.15	0.25	0.98	0.87	0.89	0.95
73	28.8	31.3	34.9	1.03	1.12	1.20	0.03	0.12	0.20	0.59	0.71	0.73	0.55
97	28.6	30.2	32.9	1.02	1.08	1.13	0.02	0.08	0.13	0.40	0.48	0.50	0.45
117	28.6	29.9	32.6	1.02	1.07	1.12	0.02	0.07	0.12	0.40	0.42	0.45	0.40
148	28.3	29.0	31.1	1.01	1.04	1.07	0.01	0.04	0.07	0.20	0.24	0.27	0.20

According to this interpretation, viscosity measurements in phosphoric acid are not a measure of molecular size at all but rather a measure of the degree of degradation of the fiber into primary chain molecules, the true "molecules" of cellulose. Thus the slopes of the curves are not a measure of hydrolysis of the 1,4-glycosidic bonds. The chemical reaction which takes place in phosphoric acid during viscosity measurements is identical with the action of weak acids upon cotton producing hydrocellulose—that is, splitting of semiacetal linkages and hydrogen bonds. Although in phosphoric acid this is a relatively slow process, it is at least one thousand times as fast as the hydrolysis of the 1,4-glycosidic bonds, for the rate constant of which—after the first 4 to 6 hours—Stamm and Cohen [11] gave the value of 7.05×10^{-6}. Thus, when cotton is treated with phosphoric acid, the initial rapid process of semiacetal hydrolysis begins as soon as some of the fiber structure is loosened and, after rupture of hydrogen bonds, large molecular "aggregates" are able to go into colloidal solution through solvation of their freed OH groups. These huge particles cause the tremendous viscosities observed with these solutions. By catalyzing the hydrolysis of the semiacetal linkages, the phosphoric acid continues to split the aggregates down into smaller and smaller units, and, as a consequence, the viscosity of the solution diminishes. After a comparatively short time the solute is completely "dispersed," with the formation of primary chain molecules. But at this point the viscosity is extremely low compared to the values customarily thought of as valid for "cellulose molecules." This would bear out McBain and McBain's conclusions [5] that the viscosity values of cellulose solutions have been far greater than one should expect for the size and shape of a cellulose molecule.

The low viscosity value of a hydrocellulose is simply then the measure of the splitting up of the semiacetal linkages in the fiber which had previously been taking place during the acid treatment of cellulose. The fact that both cotton and hydrocellulose curves

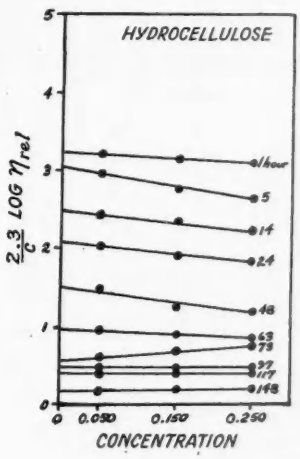

FIG. 3. $\frac{2.3}{c}\log\eta_{rel}$ *versus concentration of hydrocellulose in 100 ml. 85 percent phosphoric acid.*

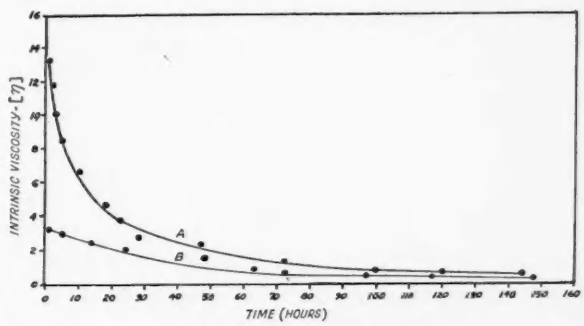

FIG. 4. *Intrinsic viscosity versus time. A—Cotton in 85 percent phosphoric acid. B—Hydrocellulose in 85 percent phosphoric acid.*

sink to approximately the same value (within the limits of accuracy on our apparatus) thus presumably indicates that little actual hydrolysis of true 1,4-glycosidic bonds occurred. Thus the initial values have no significance whatsoever in terms of true molecular weight.

By changing the conditions of preparation of the solution, entirely different viscosities can be obtained. As an example, we dissolved a cotton sample in phosphoric acid using a Waring high-speed stirrer instead of a shaker. After 10 minutes of stirring the solution was clear and showed no viscosity increase over the solvent. Yet, upon dilution with water, the cellulose settled out as white, flocculent precipitate, thus indicating that high-polymer material was still present. In addition, this material did not show a significantly greater reducing power than the original cotton. We attribute the absence of viscosity in the phosphoric acid solution so obtained to the rapid hydrolysis of the semiacetal linkages and rupture of hydrogen bonds at the high temperature developed in the Waring Blendor during the high-speed agitation.

If these viscosity curves were indeed a measure of hydrolysis of 1,4-glycosidic bonds, considerable glucose should be formed in a reasonably short period of time—for instance, a week, when the viscosity of the solution usually becomes equal to that of the solvent. Since glucose is optically active, it can be identified by polarimetric methods. A solution of glucose in 85 percent phosphoric acid gives an initial specific rotation of $[\alpha]_D^{20} = +68.0°$. Cellulose in the same solvent has a rotation of $[\alpha]_D^{20} = 0°$, which value remains unchanged for an observation period of several weeks, a period of time quite beyond the length of time during which the viscosity changes were observed.

B. Hydrolysis of 1,4-Glycosidic Bonds in Cellulose

In the light of the conclusions reached in this and the preceding paper of this series [7], it can be asked when does hydrolysis of 1,4-glycosidic bonds occur, for it is a well-known fact that glucose can be prepared from cellulose. It should be emphasized that the mechanism postulated in the foregoing discussions applies only to the problems under consideration, namely, such phenomena as hydrocellulose formation and viscosity changes in phosphoric acid. Hydrolysis of true glycosidic bonds does occur during these reactions but its effect is negligible. Strong mineral

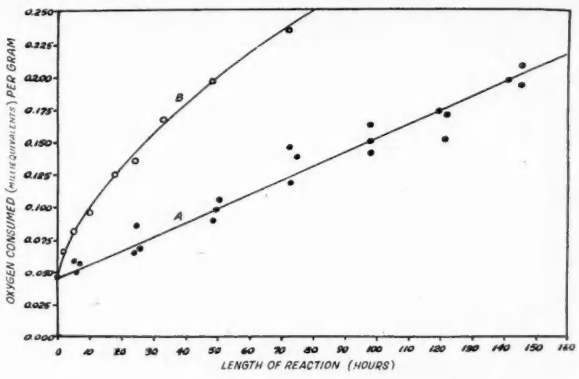

FIG. 5. *Rate of hydrolysis of cellulose in (A) 85 percent phosphoric acid, (B) 62 percent sulfuric acid.*

acids will indeed cause hydrolysis all the way to glucose if the attack is sufficiently severe and prolonged, but this is a much slower process than the initial attack of acids on cellulose, and, therefore, constitutes a problem quite distinct from the phenomena of viscosity fall and hydrocellulose formation. This conclusion is substantiated by the following experiments.

We wished to follow the rate of hydrolysis at 20°C of the true glycosidic bonds in phosphoric acid by end-group analysis using the method of potassium permanganate titration presented in Part V of this series [12]. However, several difficulties were encountered experimentally, the most serious being the fact that potassium permanganate reacts with 85 percent phosphoric acid, apparently forming some sort of colorless compound. Nevertheless, this was finally overcome by diluting with water the cellulose solution in phosphoric acid just before titration with potassium permanganate. Otherwise the procedure for titration was essentially the same as heretofore presented.

Three sets of samples were used for the experiment: surgical cotton, hydrocellulose prepared from this cotton by treatment with 5*N* sulfuric acid at 60°C for 3 hours, and viscose rayon. Samples of 0.25 gram were weighed out and each dissolved in 100 ml. of 85 percent phosphoric acid. Each sample was allowed to stand for a definite time interval at 20°C and then the solution was diluted to 500 ml. with ice and distilled water, the temperature being brought down to 0°C in this process. The permanganate titration was then performed as described previously [12], the permanganate being allowed to react for 40 minutes with the solution. The results are shown in Table III and Figure 5 (Curve A).

TABLE III. HYDROLYSIS RATE IN 85 PERCENT PHOSPHORIC ACID AT 20°C

0.25-gram samples
Reagents: 0.1076*N* potassium permanganate
0.0585*N* ferrous ammonium sulfate

Sample No.	Length of reaction (hrs.)	Total volume $KMnO_4$ added (ml.)	Volume $Fe(NH_4)_2(SO_4)_2$ added (ml.)	Milliequivalents $KMnO_4$	Milliequivalents $Fe(NH_4)_2(SO_4)_2$	Milliequivalents oxygen used up	Milliequivalents oxygen used up per g.
A. Cotton							
—	—	7.61	13.97	0.819	0.817	0.002	0.008
1	6	8.01	14.50	0.862	0.848	0.014	0.056
2	25	7.79	14.04	0.838	0.821	0.017	0.068
3	49	7.91	14.14	0.851	0.827	0.024	0.096
4	74	7.80	13.76	0.839	0.805	0.034	0.136
5	97	7.96	14.03	0.856	0.821	0.035	0.140
6	118	8.05	14.07	0.866	0.823	0.043	0.172
7	144	8.07	14.02	0.868	0.820	0.048	0.192
B. Hydrocellulose							
—	—	7.76	14.24	0.835	0.833	0.002	0.008
1	5	7.82	14.17	0.841	0.829	0.012	0.048
2	24	7.91	14.19	0.851	0.830	0.021	0.084
3	48	8.00	14.34	0.861	0.839	0.022	0.088
4	72	7.97	14.05	0.858	0.822	0.036	0.144
5	96	8.05	14.17	0.866	0.829	0.037	0.148
6	121	8.13	14.24	0.875	0.833	0.042	0.168
7	145	8.11	14.04	0.873	0.821	0.052	0.208
C. Rayon							
—	—	7.70	14.15	0.829	0.828	0.001	0.004
1	4	7.91	14.32	0.851	0.838	0.013	0.058
2	23	7.94	14.32	0.854	0.838	0.016	0.064
3	50	7.87	14.04	0.847	0.821	0.026	0.104
4	72	8.03	14.27	0.864	0.835	0.029	0.116
5	97	8.10	14.17	0.872	0.829	0.043	0.172
6	120	8.05	14.17	0.866	0.829	0.037	0.148
7	140	8.13	14.12	0.875	0.826	0.049	0.196

It is observed that all three materials show approximately the same rate of hydrolysis. The margin of error is not as small as could be desired mainly because of the problem of diluting the solution and of titrating a large volume. Nevertheless, it can be seen that the rate of hydrolysis is quite slow, as expected, thus confirming the results of af Ekenstam [9] and of Stamm and Cohen [11]. On the basis of extending the slope of the line shown (Curve A, Figure 5), it can be calculated that it would take a great many

TABLE IV. HYDROLYSIS RATE OF COTTON IN 62 PERCENT SULFURIC ACID ($d_4^{20} = 1.520$) AT 0°C

1-gram samples
Reagents: 0.1076*N* potassium permanganate
0.0585*N* ferrous ammonium sulfate

Sample No.	Length of reaction (hrs.)	Total volume $KMnO_4$ added (ml.)	Volume $Fe(NH_4)_2(SO_4)_2$ added (ml.)	Milliequivalents $KMnO_4$	Milliequivalents $Fe(NH_4)_2(SO_4)_2$	Milliequivalents oxygen used up per g.
—	—	15.07	27.68	1.622	1.619	0.003
1	2	16.86	29.90	1.814	1.749	0.065
2	5	16.10	28.22	1.732	1.651	0.081
3	10	16.40	28.56	1.765	1.671	0.094
4	18	16.74	28.65	1.801	1.676	0.125
5	24	16.04	27.22	1.726	1.592	0.134
6	33	15.87	26.32	1.708	1.540	0.168
7	48	16.23	26.50	1.746	1.550	0.196
8	72	16.55	24.72	1.781	1.446	0.235

months to hydrolyze the cellulose to glucose in 85 percent phosphoric acid.

Freudenberg and coworkers [13] have measured the hydrolysis of cellulose at 18°C and 30°C in strong sulfuric acid solutions, such as solutions of 51 percent ($d^{18} = 1.415$) and of 65 percent ($d_{18}^{18} = 1.561$) concentration of sulfuric acid by weight. These authors followed the hydrolysis by the hypoiodite method of end-group analysis and by optical rotation measurements.

We have carried out similar experiments on cotton at 0°C in 62 percent sulfuric acid solution ($d_4^{20} = 1.520$) and determined the end-groups by potassium permanganate oxidation [12]. One-gram samples of surgical cotton were dissolved in 100 ml. of the acid solvent at 0°C. When the desired time interval was completed, each solution was diluted with an equal volume of ice and distilled water, the temperature being maintained at 0°C. Titrations were then carried out as before with potassium permanganate. The results are shown in Table IV and Figure 5 (Curve B).

It is seen that the hydrolysis of the glycosidic bonds under the experimental conditions is quite slow, although faster than in 85 percent phosphoric acid. This is in agreement with Freudenberg and coworkers' results according to which 50 to 60 days are required for the complete degradation of cellulose at 18°C in 51 percent sulfuric acid.

Summary

The viscosity of a solution of surgical cotton in 85 percent phosphoric acid was found rapidly to diminish with time and soon reach very low values. The viscosity of a hydrocellulose solution did not show nearly so high an initial viscosity but also decreased to very low values, which were beyond the range of exact viscosity measurements.

The large drop in viscosity is not caused by hydrolysis of 1,4-glycosidic bonds but it is the result of hydrolytic cleavage of semiacetal linkages and rupture of hydrogen bonds. Therefore, large molecular aggregates, secondary chain molecules rather than primary chain molecules, true cellulose molecules, are responsible for the great viscosity of cellulose solutions.

Aged cellulose solutions in 85 percent phosphoric acid show no optical rotation; hence no glucose is being formed by hydrolysis of cellulose in these solutions upon standing even for a considerable period of time.

End-group analyses of cellulose by the potassium permanganate method in 85 percent phosphoric and 62 percent sulfuric acids show that the rate of hydrolysis of the 1,4-glycosidic bonds is extremely slow and is not involved in the phenomena of hydrocellulose formation and viscosity decreases.

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Elastic Recovery in Cotton Knitted Fabrics

Arnold M. Hansen * and Hazel M. Fletcher †

IN the past few years production of knitted fabrics has increased markedly. Quantities of knit underwear and outerwear fabrics for sale to manufacturers mounted from 75,531,600 pounds in 1943 to 88,685,100 pounds in 1945.‡

Knitted fabrics are taking precedence over woven fabrics for many purposes—chiefly because of their elastic properties which allow them to stretch considerably, even under small stresses, and yet later return to their original shape. Most woven materials stretch very little.

The amount of stretch and the elastic recovery, also called "recoverable stretch," determine the suitability of knitted fabrics for specific uses. For example, a fabric that stretches little is a poor selection for a slip-on sweater. On the other hand, one of minimum stretch but high recovery is desirable for gloves. Hose with considerable stretch and high recovery are always in demand. In fact, elastic recovery is greatly to be desired in all knitted fabrics.

Since stretch and elastic recovery are of such great importance in knitted fabrics, evaluation of these properties for fabrics of various constructions made of different kinds of yarns is greatly needed. The results of such evaluations would be useful to the technologist who wants to create fabrics for special purposes, to the research worker in comparing the elastic properties of various fabrics, and to the consumer as an aid in purchasing knitted fabrics for a specific need.

Comprehensive research has been done on the elastic recovery of fibers, both natural and synthetic, under various stresses and strains [3, 5, 6]. However, the investigations on elastic recovery of knitted fabrics have been confined to hosiery [1, 2, 4]. This paper reports the elastic recovery in the crosswise direction at various stresses and strains of certain plain knitted fabrics made of natural and mercerized carded and combed cotton yarns.

Schiefer and Cleveland [4] measured the elasticity of women's hose by determining the algebraic difference between the circumference of the stocking at a load of 30 pounds in the first cycle made by a hosiery-testing machine and the circumference at a load of 10 pounds in the two-hundredth cycle of distension. Other investigators [1, 2] using the same equipment expressed an estimate of the elastic properties of women's hose by the ratio of recovery load to stretch load. Both loads were read at 19.2 inches circumference of the stocking on the two-hundredth cycle.

For these two methods the fabric must be in the form of a stocking. Thus, when they are used, various construction factors pertaining to the shape of the stocking must be held constant to compare fabrics in which only one factor, such as fiber content, varies. To date, no method has been described in the literature whereby the elastic recovery of small specimens of knitted fabrics can be measured.

A method was devised, therefore, using a machine commonly employed in determining the breaking

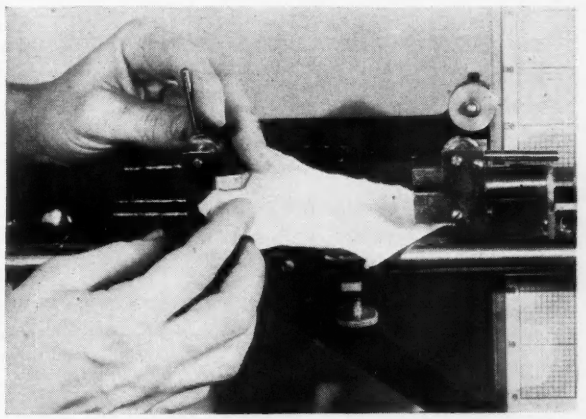

FIG. 1. *Incline plane serigraph machine shown with jaws for knitted fabrics.*

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‡ Information obtained from annual summaries on "Underwear, Knit Cloth, and Knit Fabric Gloves," and from monthly releases on "Underwear and Knit Cloth for Sale" for 1945, "Facts for Industry," Series M67C. U. S. Bureau of Census.

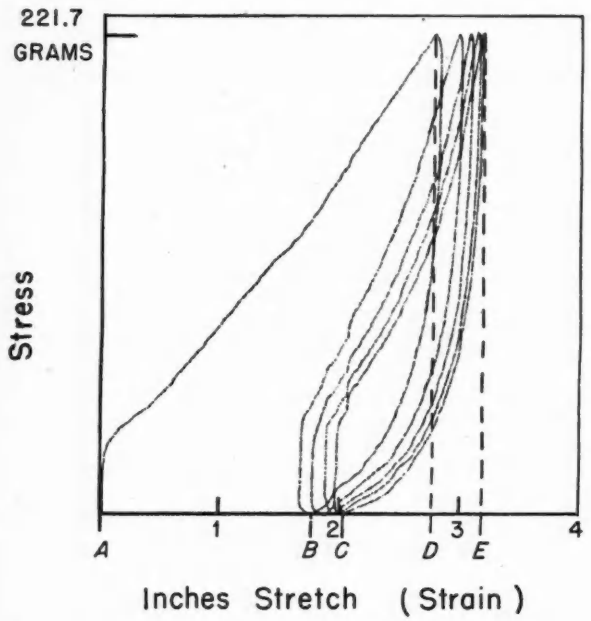

FIG. 2. *The cyclic stress-strain curves at a maximum load of 221.7 grams for a plain knit cotton fabric in crosswise direction.*

strength and elongation of yarns. In this procedure the amounts of recovery are calculated from hysteresis loops of stress-strain curves formed by this apparatus.

Materials

Fabrics knit from four commercial yarns were included in this study. The yarns were 36/1 carded short-staple peeler cotton, natural and mercerized, and 36/1 combed medium-staple peeler cotton, natural and mercerized. Each of these yarns was knit on a 42-gage full-fashioned hosiery machine in the laboratory of the Bureau of Human Nutrition and Home Economics, into plain knit fabrics having 32 and 44 courses per inch, thus making eight experimental fabrics in all.

In order to dissolve the natural wax as well as that applied before knitting, the fabrics were immersed for two hours in an organic solvent, dried, and rinsed in distilled water at 100°F. Afterwards they were laundered in a launderometer for 30 minutes at 100°F with a 0.5-percent solution of neutral soap in distilled water. They were then squeezed out by hand and rinsed four times for 2-minute periods at 100°F. The fabrics were laid out smoothly, without stretching, on a flat surface and allowed to dry. Care was taken not to distort the

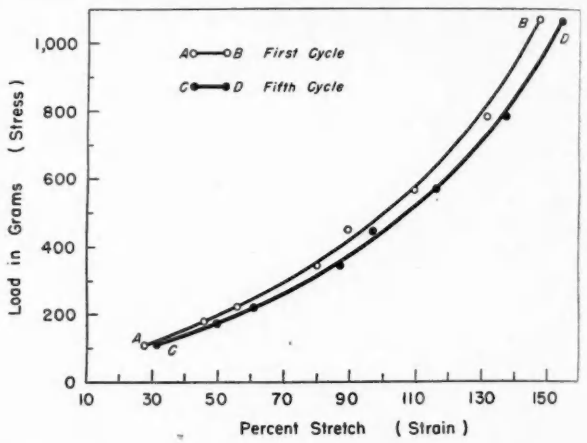

FIG. 3. *First and fifth cycles of stress-strain curves for fabric knitted of mercerized combed cotton with 44 courses per inch.*

fabric before testing because any applied stress would change the elastic properties.

Apparatus

Since any measured value of elastic recovery is dependent on the time factor of deformation, arbitrary conditions for determining this property were set up.

A constant-rate-of-loading, incline plane, serigraph type of machine designed to determine the breaking strength of yarns was used. To utilize this machine for testing the knitted fabrics, a wider and more substantial set of jaws was designed and constructed to hold the pieces of material. These jaws, 1 inch in width and interchangeable with the original jaws supplied with the machine, were placed on the machine with openings facing one another, so that a piece of fabric could be clamped between them (Figure 1). The machine was then operated in the

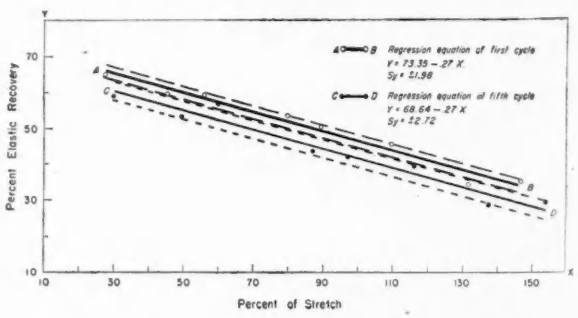

FIG. 4. *First and fifth cycles of elastic recovery-strain curves for fabric knitted of mercerized combed cotton with 44 courses per inch (regression lines and standard errors of estimate).*

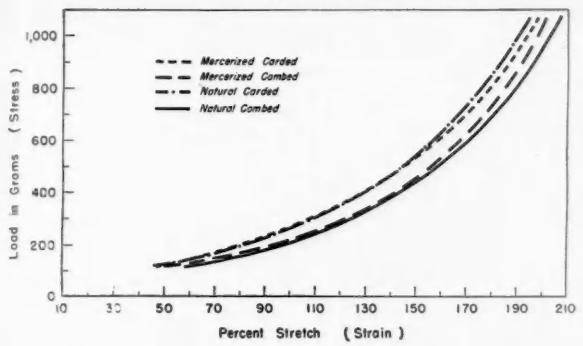

FIG. 5. *Stress-strain curves (first cycle) of plain knit fabrics of 32 courses per inch made of natural and mercerized carded and combed cotton yarns.*

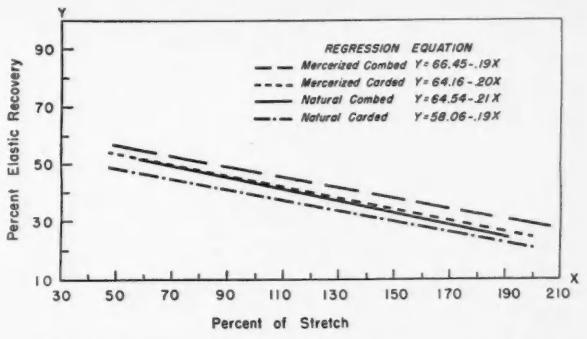

FIG. 6. *Elastic recovery-strain curves (first cycle) of plain knit fabrics of 32 courses per inch made of natural and mercerized carded and combed cotton yarns.*

same manner as when testing yarn. Since the jaws used for testing fabric were heavier than the original ones the machine was calibrated for the loads used in this experiment.

With the fabric jaws the rate of loading for loads ranging from 117.5 to 566.5 grams applied in this study was 9.9 grams per second. The rate of loading for loads greater than 566.5 grams was 18.7 grams per second.

To eliminate the slack in the knitted fabric at the beginning of each test a device was developed whereby the slack could be removed without stretching the fabric. This made it possible to measure and mark all samples under the same tension. The tension device consisted of two clamps, one stationary, the other mounted on a carriage, the wheels of which were fitted with ball bearings. To the other end of the carriage was attached a cord, running over a pulley, to which weights could be added. Two stylus pens were mounted on the base of the instrument in such a manner that when lowered they would mark a definite space on the fabric between the clamps.

Procedure

Before any measurements were made the fabrics were allowed to come to equilibrium with an atmosphere having a relative humidity of 65 percent and a temperature of 70°F, the standard conditions for textile testing.

Elastic recovery in the crosswise direction was determined for the eight knitted fabrics. Specimens of the material were cut 4 inches crosswise and 2 inches lengthwise. Each sample was then clamped into the tension device under a reproducible tension of 6 grams, which was just sufficient to straighten but not to stretch the fabric. While under tension the gage length was marked. A gage length of 3 inches was used for all determinations except when

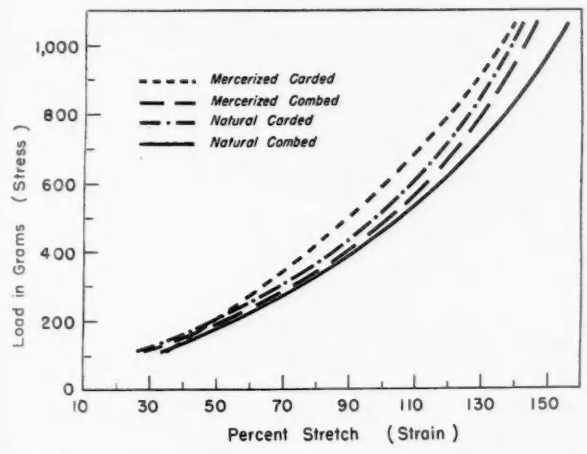

FIG. 7. *Stress-strain curves (first cycle) of plain knit fabrics of 44 courses per inch made of natural and mercerized carded and combed cotton yarns.*

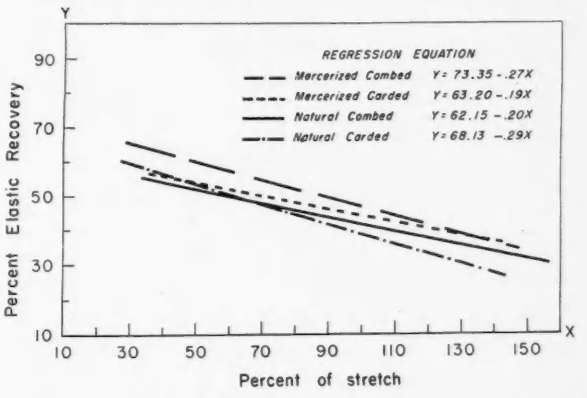

FIG. 8. *Elastic recovery-strain curves (first cycle) of plain knit fabrics of 44 courses per inch made of natural and mercerized carded and combed cotton yarns.*

the load was so large as to stretch the fabric beyond the capacity of the machine. Then a 2-inch length was used.

The jaws were set for the proper gage length, and the specimen was clamped into the jaws of the machine at the marks indicating the gage length.

Five cyclic stress-strain curves were made for each specimen. For each knitted fabric three specimens were used for each of eight different loads ranging from 117.5 to 1,067.1 grams. Before a test was started the machine was set for a definite maximum load and the setting was not changed until the three specimens had been examined.

The total stretch and recoverable stretch were read from the cyclic stress-strain diagram, and the elastic recovery was calculated. The means of stretch and elastic recovery at the same maximum load for the first and fifth cycles were obtained for three specimens. The results for eight maximum loads were used in plotting stress-strain and elastic recovery-strain curves.

The definition of elastic recovery used for knitted fabrics is identical with that used for fibers by Meredith [3], Schramek and Hempel [5], and others—that is, elastic recovery is the ratio of recoverable strain (recoverable stretch) to total strain at any given stress.

Figure 2 shows typical hysteresis loops of stress-strain curves at a maximum load of 221.7 grams for a plain knit cotton fabric in the crosswise direction. AD and BD are the total and recoverable stretch, respectively, for the first cycle; likewise, AE and CE are the total and recoverable stretch for the fifth cycle.

Results and Discussion

The results for all fabrics showed that the percent of strain increased with the stress applied. The materials also stretched more in the fifth cycle than in the first. These stress-strain relations are shown in Figure 3 for the fabric knit of combed mercerized cotton with 44 courses per inch.

It was found that the elastic recovery-strain data for all the fabrics approximated straight lines. Figure 4 shows the regression lines of these data for the first and fifth cycles for the combed mercerized cotton fabric. These lines are parallel and indicate that the elastic recovery diminishes with the amount of stretch.

Figures 5, 6, 7, and 8 show stress-strain and elastic recovery-strain curves for the eight fabrics for the first cycle. A comparison of Figures 5 and 7 indicates that the fabrics of 32 courses per inch stretched considerably more than those of 44 courses per inch. Combed yarns produced fabrics with greater stretch than fabrics made of carded yarns.

It is evident from Figures 6 and 8 that the two groups of fabrics were similar in elastic recovery for any given strain. In each group, for nearly all strains, fabrics knit from mercerized yarns had greater elastic recovery than those made from the natural, and the fabrics knit of combed cotton yarn had greater elastic recovery than those knit of carded cotton yarn.

Summary

The elastic recovery of fabrics knitted from natural and mercerized carded and combed cotton yarns was determined by means of hysteresis loops of stress-strain curves. A machine used in measuring breaking strength and elongation of yarns was adapted for this purpose.

For any given stress all the knitted fabrics made of natural and mercerized carded and combed cotton yarns exhibited a decrease in their elastic recovery with the number of loading cycles. In the main the elastic recovery was greater for fabrics knit of mercerized cotton yarn than for those knit of natural cotton yarn; also, those knit of combed cotton had greater elastic recovery than fabrics of carded cotton.

The method devised in connection with this study for determining the elasticity of a knit fabric uses hysteresis loading curves having an arbitrary time cycle. This procedure requires only small specimens, thus saving a substantial amount of fabric. It also provides a means whereby a part of a knitted article—such as the boot or the heel of a stocking—can be studied independently, without the influence of one part upon another.

Acknowledgment

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Effect of Skein Length on Yarn Number and Strength Determinations of Cotton Yarns

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Introduction

The skein test is customarily used in cotton mills in this country for determining yarn number and strength. A skein containing 120 yards of yarn which has been wound upon a reel having a 1½-yard perimeter is known as the standard skein [1]. While the worth of the test for research purposes is questionable, its use for production control has proved valuable and, in most instances, entirely adequate.

It is the purpose of this paper to present some data which seem to demonstrate the practicability of using a much shorter-length skein than the standard skein, but having the same circumference. In this work, skeins of varying lengths were prepared from each of the 13 yarns used for experimentation. These were then tested for yarn number and strength, and the average results obtained from each skein length for a specified yarn were compared. Other pertinent data, including the coefficients of variation of yarn number and strength for each series of tests, are also given.

Previous Work

No comprehensive data appear in the literature on the effects of skein length on yarn number and strength. W. J. Hall [2] gives a limited amount of information from tests upon 16/2 cotton yarn. His investigations pertained principally to a study of single-thread and skein breaking strengths upon worsted and woolen yarns, the use of cotton yarn being only incidental. As hooks were used for holding the skein in the tensile testing machine, the strands of yarn were crowded together, and each strand was thus given some support by those adjacent to it. This supporting friction of course varied with different lengths of skeins. The use of hooks has long since been discarded in this country for the conventional spools. For worsted or woolen yarn, Hall advocates the use of not less than 45-yard skeins but does not recommend a minimum length for cotton yarns.

Midgley and Peirce [3] show the relation of strength between 30-, 60-, and 120-yard skeins of No. 60 cotton yarn in tests made during an extensive investigation of single thread versus lea strength determinations. These investigators used hooks, as Hall had done. They state that friction between the yarns, increased by carelessness in placing the skein upon the hooks, may be diminished by use of smaller skeins with the speed of the pulling hook reduced somewhat below the speed used to break the standard skein. Their findings show that 60-yard skeins broke at about 90 percent, and 30-yard skeins at about 85 percent of the lea, or 120-yard skein. The results would appear to be rather inconclusive, especially in view of the use of hooks instead of the improved present-day spools, and of only one type of cotton yarn used.

Experimental Procedure

The 13 yarns used in this study comprised "singles," 2-ply and 4-ply, ranging from 4s to 80/2, with breaking strengths ranging from 47 to 668 pounds, based upon 120-yard skeins. All reelings and tests were performed in an atmosphere of 65 percent relative humidity at 70°F, the yarns having been previously exposed to this standard condition for at least 24 hours.

An electrically driven reel operating at a uniform rate of speed, which could be stopped at any desired yardage, was employed for winding the skeins. A uniform tension was applied to the yarn, and the finishing end of the skein was tied to the starting end in a square knot.

Breaking strengths were determined upon stand-

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TABLE I. YARN NUMBER AND COEFFICIENTS OF VARIATION FOR DIFFERENT SKEIN LENGTHS OF 13 COTTON YARNS

Skein length (yds.)	4s Warp carded	9s Filling carded	16/4 Warp carded	20s Warp combed	20/2 Warp combed	23s Warp carded	30s Warp combed	31s Warp carded	40s Warp combed	40s Filling carded	40/2 Warp combed	40/4 Warp combed	80/2 Warp combed
	Number of tests for each skein length of a specific yarn												
	10	30	10	30	30	40	20	20	20	20	10	10	20
	Average yarn number for each skein length*												
12	4.2	9.0	16.1	19.9	20.3	22.9	29.5	30.9	38.6	38.3	39.8	38.4	73.9
24	—	—	—	—	—	—	29.9	30.7	38.4	38.3	—	—	72.9
36	4.1	9.1	—	20.1	20.1	—	29.5	30.3	38.6	40.0	37.6	39.0	74.4
60	4.1	9.1	—	20.1	20.3	—	29.2	30.5	38.6	39.1	40.2	38.4	74.0
84	4.1	9.1	16.4	20.2	20.4	—	—	—	—	—	39.1	37.9	—
108	—	9.1	—	20.1	20.2	—	—	—	—	—	41.1	38.8	—
120	4.2	9.1	16.0	20.3	20.3	23.5	29.3	30.4	39.3	38.8	41.9	38.4	73.8
Average	4.1	9.1	16.2	20.1	20.3	23.2	29.5	30.6	38.7	38.9	40.0	38.5	73.8
	Coefficients of variation (percent)												
12	4.05	5.11	2.24	2.01	2.61	3.19	2.75	4.69	5.44	5.90	5.78	4.22	1.76
24	—	—	—	—	—	—	2.07	4.56	2.92	5.95	—	—	3.16
36	4.63	4.62	—	2.49	2.59	—	2.37	2.90	3.21	6.02	5.85	3.08	1.38
60	4.39	5.16	—	2.74	2.96	—	2.05	4.66	2.31	4.37	5.62	3.75	1.50
120	3.10	5.05	0.69	1.97	1.72	1.19	1.20	3.45	5.16	5.36	3.46	2.94	1.96

* Ply yarns were computed as "singles."

ard testing machines of the pendulum type with capacities of 50, 150, 300, and 800 pounds. The speed of the pulling spool was $12 \pm \frac{1}{2}$ inches per minute. In most instances the different skein lengths of a specific yarn were tested upon one machine, to reduce as far as possible any variation in results that might occur even when using two carefully calibrated testing machines. Average breaking strengths were corrected to the specified yarn number in accordance with the formula suggested by Committee D-13 of the A.S.T.M. [1].

For determining the yarn number (size or count) each broken skein was weighed immediately after its strength had been recorded.

Preparation of Test Specimens

For 10 of the 13 yarns, skeins were reeled from only one bobbin; for each of the remaining 3 yarns (9s, 20s, and 20/2), two bobbins from the same spinning frame were used. Only one bobbin was used in the majority of cases because it was believed there would thus be greater uniformity in yarn size and strength and elimination, as far as possible, of the larger variations in spinning that sometimes occur between two or more bobbins.

The procedure followed in selecting different skein lengths for a specific yarn varied somewhat in the order of reeling. For example, from the bobbin containing 23s yarn, there was first reeled off a 12-yard skein, then one of 120 yards, and so on until 40 skeins of each length were obtained. These 40-skein tests represent the two extremes in skein lengths and were the largest number of comparative tests employed in this study. For another yarn, skeins were reeled as follows: First, 12 yards; second, 120 yards; third, 24 yards; fourth, 36 yards; and fifth, 60 yards. This order was repeated until there were 20 skeins of each length. Several other sequents of skein reeling were employed with a view to obtaining the best comparability of test results between each skein length used for a specific yarn.

Of the 13 yarns used in this investigation, 5 were produced by cotton mills whose product is considered to be representative of particularly good manufacturing conditions. These are: 30s combed, 31s carded, 40s combed, 40s carded, and 80/2 combed. Twenty skeins of 12, 24, 36, 60, and 120 yards of each of these 5 yarns were tested for breaking strength and yarn number.

Yarn Number

The results of tests for yarn number upon skeins of different lengths for each of the 13 yarns used in the study are shown in Table I. The blank spaces in the table indicate that an insufficient length of yarn was contained upon a bobbin, or bobbins, to

TABLE II. YARN NUMBER VARIATION IN 20 TESTS OF EACH SKEIN LENGTH, AND DIFFERENCE BETWEEN THE AVERAGE OF THE FIRST AND SECOND 10 DETERMINATIONS OF EACH 20 TESTS

Yarn designation	Skein length Yds.	Maximum variation in 20 tests No.	Average of: First 10 tests No.	Second 10 tests No.	Difference between first and second 10 tests* No.
30s Warp combed	12	3.5	28.9	30.0	+1.1
	24	1.6	29.9	29.9	0.0
	36	2.6	29.5	29.5	0.0
	60	3.4	29.3	29.0	−0.3
	120	1.5	29.3	29.2	−0.1
31s Warp carded	12	6.7	31.0	30.8	−0.2
	24	5.8	31.0	30.4	−0.6
	36	2.7	30.6	29.9	−0.7
	60	6.0	31.1	29.9	−1.2
	120	3.8	30.1	30.7	+0.6
40s Warp combed	12	7.8	38.3	38.8	+0.5
	24	3.8	38.1	38.7	+0.6
	36	5.4	38.6	38.5	−0.1
	60	3.2	38.4	38.9	+0.5
	120	6.2	39.6	39.0	−0.6
40s Filling carded	12	7.5	38.2	38.3	+0.1
	24	9.1	37.6	39.0	+1.4
	36	9.4	38.6	41.4	+2.8
	60	7.3	38.8	39.3	+0.5
	120	8.1	39.0	38.5	−0.5
80/2 Warp combed	12	5.2	73.8	74.1	+0.3
	24	8.0	73.0	72.8	−0.2
	36	2.7	74.5	74.2	−0.3
	60	5.0	73.4	74.6	+1.2
	120	5.5	74.0	73.6	−0.4

* Plus or minus, based upon first 10 tests.

run the seven skein lengths listed in the first column. There appears to be no consistent trend of yarn number with skein length, and none of the determinations with different skein lengths differ appreciably for the average of all lengths. The coefficients of variation give a measure of the relative spread, or variability, of the individual data about their mean value. As is to be expected, the yarn number determinations are, on the average, slightly more variable for the shorter skein lengths. The more uneven the yarn, the greater will be this tendency and, as a consequence, the shorter lengths will detect unevenness better than those made on the longer lengths.

The first analysis of individual results obtained from tests upon different skein lengths of the 5 yarns produced under particularly good manufacturing conditions is presented in Table II. The data show the wide difference in yarn number that may occur in supposedly uniformly spun yarns. For instance, the results of 20 determinations by the standard method of test upon 40s combed warp yarn, taken from one bobbin, gave a maximum variation of 6.2 yarn numbers. Similarly, 40s carded filling yarn varied 8.1 yarn numbers. In the last column of the table are shown the differences between the average of the first and second 10 determinations of each skein length. These differences are insignificant and, in the case of these 5 uniform yarns, indicate no tendency to vary with the length of skein, the 12-yard skeins being just as stable, on the average, as the 120-yard skeins.

A consideration of the data in Tables I and II leads to the conclusion that 12-yard skeins should be entirely satisfactory for determining yarn numbers.

Breaking Strengths

For purpose of comparability, the average breaking strength of each skein length for each yarn was corrected to the specified yarn number [1]. These results are given in Table III and are plotted in Figure 1. The graph shows, with few exceptions, that the strengths of different skein lengths of a specified yarn fall with great regularity on a straight line. (Skeins of 84- and 108-yard lengths for several of these yarns, selected in the manner described in the section "Preparation of Test Specimens," are included in the graph; however, because of their nearness in length to the 120-yard skein, they are not discussed in this paper.) Coefficient-of-variation data are presented to show the relative spread of the individual skein breaks about their average, for each skein length. As in the case of yarn number, the spread of the individual breaks tends to increase with the shorter-length skein. It is believed, however, that for most control testing in a cotton mill the differences would not be significant. The data given in the lower portion of Table III show more clearly the relative breaking strengths of the different skein lengths of each yarn, as each figure represents a common basis of 120 yards. The strengths of skeins less than 120 yards were computed from the results shown in the table under "Average breaking strength of each skein length," as follows: breaking strengths of 12-yard skeins were multiplied by 10; 24-yard skeins by 5; 36-yard skeins by 33⅓; and so on, for each skein length up to 120 yards.

TABLE III. BREAKING STRENGTH (IN POUNDS) AND COEFFICIENTS OF VARIATION FOR DIFFERENT SKEIN LENGTHS OF 13 COTTON YARNS

Skein length (yds.)	4s Carded	9s Carded	16/4 Carded	20s Combed	20/2 Combed	23s Carded	30s Combed	31s Carded	40s Combed	40s Carded	40/2 Combed	40/4 Combed	80/2 Combed
	Number of tests for each skein length of a specific yarn												
	10	30	10	30	30	40	20	20	20	20	10	10	20
	Average breaking strength of each skein length*												
12	57.71	21.02	67.36	11.80	29.11	10.63	8.11	7.27	6.02	5.11	11.93	31.3	8.35
24	—	—	—	—	—	—	15.60	13.92	11.87	9.39	—	—	16.26
36	167.6	60.97	—	36.8	86.9	—	23.88	19.90	16.98	13.76	34.4	96.8	23.67
60	275.9	102.2	—	62.3	143.3	—	39.84	33.80	27.79	22.86	63.2	159.6	39.95
84	398.8	140.3	465.0	86.2	198.6	—	—	—	—	—	85.5	227.3	—
108	—	—	—	111.4	256.7	—	—	—	—	—	109.7	298.6	—
120	549.0	203.7	668.2	124.1	283.8	105.0	78.24	68.29	57.12	45.76	120.6	317.6	79.28
	Coefficients of variation (percent)												
12	7.47	13.03	3.43	7.88	3.23	8.09	7.13	7.63	7.38	6.24	6.71	7.60	7.04
24	—	—	—	—	—	—	4.74	7.96	4.38	7.18	—	—	5.26
36	8.64	12.80	—	4.81	5.63	—	4.81	6.83	4.82	8.69	6.10	4.56	8.35
60	5.94	13.16	—	5.30	5.13	—	3.51	5.50	4.68	7.75	6.49	7.68	4.87
120	3.21	11.49	2.33	3.87	4.16	3.81	2.89	7.19	4.75	7.99	4.15	4.50	3.69
	Breaking strengths based upon 120-yard skeins												
12	577.1	210.2	673.6	118.0	291.1	106.3	81.1	72.7	60.2	51.1	119.3	313.0	83.5
24	—	—	—	—	—	—	78.0	69.6	59.4	46.9	—	—	81.3
36	558.7	203.2	—	122.6	289.7	—	79.6	66.3	56.6	45.9	114.7	322.7	78.9
60	551.8	204.4	—	124.6	286.6	—	79.7	67.6	55.6	45.7	126.4	319.1	79.9
84	570.0	200.6	665.0	123.1	283.9	—	—	—	—	—	122.3	325.0	—
108	—	202.7	—	123.7	285.3	—	—	—	—	—	122.0	331.7	—
120	549.0	203.7	668.2	124.1	283.8	105.0	78.2	68.3	57.1	45.8	120.6	317.6	79.3

* Actual strengths corrected to their respective specified yarn number.

The data presented in Table IV show the differences which occur in a series of 20 individual breaks on the 5 yarns which were considered representative of particularly good manufacturing conditions. This table shows also the differences between the averages of the first and second 10 breaks of each skein length. It will be observed that the shorter skeins have a greater spread between individual breaks, but the differences were for the most part small. The differences between the averages of the first and second series of 10 breaks were insignificant and showed no consistent trend with skein length.

The generally lower strengths of 120-yard skeins are due largely to some overlapping of some of the 80 circuits of yarn during the reeling of a skein, and overlapping circuits are longer than those underneath. Therefore, when the skein is being broken, the underlying or shorter circuits are first subjected to tension and break before the longer circuits. The testing machine continues to record a higher strength after the first strand or strands break; thus, the

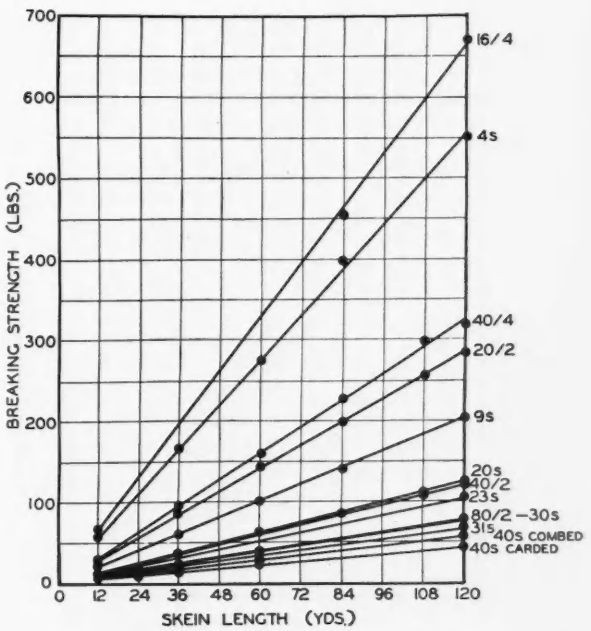

FIG. 1. *Breaking strength for different skein lengths of 13 cotton yarns.*

TABLE IV. BREAKING STRENGTH VARIATION IN 20 TESTS OF EACH SKEIN LENGTH, AND DIFFERENCE BETWEEN THE AVERAGE OF THE FIRST AND SECOND 10 DETERMINATIONS OF EACH 20 TESTS *

Yarn designation	Skein length Yds.	Maximum variation in 20 tests Lbs.	Average of: First 10 tests Lbs.	Second 10 tests Lbs.	Difference between first and second 10 tests† Lbs.
	12	19.6	79.0	83.3	+4.3
30s	24	13.4	77.5	78.5	+1.0
Warp	36	18.0	80.2	78.9	−1.3
combed	60	13.6	80.9	78.4	−2.5
	120	10.0	79.3	76.9	−2.4
	12	20.7	72.6	72.7	+0.1
31s	24	25.0	70.2	69.0	−1.2
Warp	36	16.2	66.3	66.2	−0.1
carded	60	14.7	69.2	66.0	−3.2
	120	14.2	67.7	68.9	−1.2
	12	23.4	59.6	60.6	+1.0
40s	24	11.0	59.0	59.8	+0.8
Warp	36	11.7	57.8	55.2	−2.6
combed	60	9.3	56.2	55.1	−1.1
	120	16.0	58.3	56.0	−2.3
	12	14.3	51.4	50.7	−0.7
40s	24	13.8	45.7	48.3	−2.6
Filling	36	13.7	45.6	46.1	+0.5
carded	60	13.7	45.8	45.5	−0.3
	120	13.3	46.2	45.2	−1.0
	12	18.7	83.5	83.5	0.0
80/2	24	18.1	83.6	79.0	−4.6
Warp	36	24.4	78.5	79.1	+0.6
combed	60	10.7	79.5	80.3	+0.8
	120	13.7	78.4	80.1	+1.7

* Skein strengths of 60 yards and less computed to a common basis of 120-yard skein length.

† Plus or minus, based upon first 10 tests.

final recorded strength is lower than if all circuits broke almost simultaneously, as they seem to do with the short skeins. The bulkiness of the 120-yard skeins, which tends to more nearly balance the weak and strong portions in the skeins, is another contributing factor to their lower strengths.

Conclusions

On the basis of the measurements made on 13 single and ply yarns covering a fairly wide range of numbers, it would appear that skeins of considerably shorter length than 120 yards are adequate for determining yarn number and breaking strength, and that skeins as short as 12 yards should be suitable for most production control testing. The minimum adequate length will depend, of course, on the type and uniformity of the yarn being tested and the degree of accuracy required.

Advantages of the shorter skein would be: (1) considerable time would be saved in the preparation and testing of samples; (2) the lower-capacity strength-testing machines which would be required in, for instance, mills making a wide range of yarns, would reduce the number of machines; and (3) consumption of yarn would be less.

Literature Cited

1. American Society for Testing Materials, Committee D-13 on Textile Materials, "A.S.T.M. Standards on Textile Materials" (1944).
2. Hall, W. J., *J. Text. Inst.* **7**, T223 (1925).
3. Midgley, E., and Peirce, F. T., *J. Text. Inst.* **28**, T305 (1926).

Book Reviews

Colloid Chemistry, Theoretical and Applied, Vol. VI. General Principles and Specific Industries; Synthetic Polymers and Plastics. Collected and edited by Jerome Alexander. New York, Reinhold Publishing Corporation, 1946. 1215 pp. + vii, illus. Price, $20.00.

(Reviewed by Joseph H. Brant)

Seventy-one papers or chapters comprise this volume—38 in Part I, "General Principles and Specific Industries," and 33 chapters, 3 appendices, and a supporting addenda in Part II, "Synthetic Polymers and Plastics."

The 16-page index makes reference to authors adequate and useful. The 17-page subject index, which includes multiple references, has been found adequate in every respect.

Titles of individual chapters are not included in this review. Part I covers an extensive field, and includes such diverse chapters as "Nature of Strength and Failure in Brittle Solids"; "Industrial Adhesives"; "Dispersions of Finely Divided Solids in Liquid Media"; "Lubricating Greases as Colloidal Systems"; "The Skin and Its Technological Hazards"; and "Removal and Recovery of Proteins by Water-Soluble Lignin."

Part II is equally varied in content, including such chapters as "Some Principles Underlying the Behavior of Plastics"; 30 chapters and 2 appendices, each dealing with a specific polymer, resin or resin process; 2 chapters and 1 appendix on "A New Method of Preparation and Purification of Some Hydrous Oxide Sols"; "Potential Nuclear Energy and Some Consequences of Its Release"; "Adsorption and Elution as a Concentrating Process"; and a special addenda table of dimensions.

While the print in this book is clear, the wartime restrictions of print size and page coverage are a serious deterrent to prolonged reading. The book is extensively and clearly illustrated.

The reviewer feels that, just as a single author is incapable of writing a book of such diversification, so a single reader is apt to find equal difficulty in reading the entire book with intelligent interest. This does not necessarily reduce the usefulness of the book as a whole, but does place, it seems, a premium on having so much information under a single title.

The lack of style uniformity from chapter to chapter is not a detracting feature, though more uniformity in chapter references would have been an improvement.

The reviewer believes this book will find wide use as an addition both to private libraries and to the libraries of larger organizations.

The editor as well as each contributor is to be commended on the scope of coverage and the wealth of information collected herein.

Advances in Colloid Science, Volume II. Scientific Progress in the Field of Rubber and Synthetic Elastomers. Edited by H. Mark and G. S. Whitby. New York, Interscience Publishers, Inc., 1946. 453 pages. Price, $7.00.

(Reviewed by W. E. Davis)

One of the primary aims of this book, as stated in the Introduction, is to orientate the problems of rubber among those of high polymers generally; to show how the methods used in the study of rubber, and the results obtained, can contribute to the understanding of other polymers, and vice versa. The scope of the work is indicated by the subjects covered: "Second-Order Transition Effects in Rubber and Other High Polymers," by R. F. Boyer and R. S. Spencer; "Crystallization Phenomena in Natural and Synthetic Rubbers," by Lawrence A. Wood; "The Study of Rubberlike Substances by X-Ray Diffraction Methods," by C. W. Bunn; "The Thermodynamic Study of Rubber Solutions and Gels," by Geoffrey Gee; "Significance of Viscosity Measurements on Dilute Solutions of High Polymers," by R. H. Ewart; "The Kinetic Theory of Rubber Elasticity," by E. Guth, H. M. James, and H. Mark; "Vulcanization," by E. Harold Farmer; "Rubber Photogels and Photovulcanizates," by Henry P. Stevens; "Reinforcing and Other Properties of Compounding Ingredients," by Donald Parkinson. The study of the chemical structure of

synthetic rubbers by means of ozonolysis is covered in the Introduction by G. S. Whitby.

It is obviously nearly impossible for a single reviewer to be sufficiently familiar with all the subjects covered to offer useful criticism on them. However, some inexpert remarks may be of value to those prospective readers who, like the writer, are familiar with only a few of the fields covered. The book provides quite thorough reviews of the recent literature for all the topics selected, and in nearly all cases the reviews are critical. Assumptions of previous knowledge on the part of the reader vary considerably; the chapter on x-ray diffraction methods, for example, can be read with profit whether or not the reader has an extensive knowledge of the field, while that on elasticity is considerably more difficult for the reader not familiar with the subject.

The illustrations are in general well done. There is a subject index of moderate length and a complete index of authors. The book includes a photograph and biographical sketch of the late Elmer O. Kraemer, who, in collaboration with Floyd E. Bartell and S. S. Kistler, inaugurated the series of which this is the second volume.

Kunstseide und Zellwolle nach dem Viskose-Verfahren. Dr. Kurt Götze. (In German.) Berlin, Julius Springer, 1940. Lithoprinted by Edwards Brothers, Ann Arbor, Michigan, 1944. 644 pp. + xi with 349 illustrations. Price, $20.00.

(Reviewed by LeRoy H. Smith)

This is a very comprehensive and unusually well-organized book covering all phases of the viscose process, and its value is greatly augmented by the inclusion of numerous illustrations, with descriptions, of modern machinery and other equipment employed in the newer German manufacturing plants.

The book begins with an historical review and discussion of the economic development of the industry, and this is followed by a chapter on cellulose and the structure of the fiber.

Other chapters take up the following subjects: Cellulose raw materials, cellulose pulp, testing of cellulose, yarn and staple spinning, preparation and regeneration of caustic soda solutions, swelling of cellulose in water, alkali cellulose, xanthation, viscose ripening, viscose solutions, spinning baths, construction of spinning machines, spinning operation, cutting of staple fiber, de-sulfiding, bleach and other baths, after-treatment of machinery, throwing, sorting, opening of staple, packing and preparation for shipment, and testing of the finished product.

The book is concluded with an index of patents, a name and firm index, and a general subject index.

This work is a valuable addition to the literature of the viscose rayon process, and its acquisition by technical libraries is recommended. It is felt that the price placed upon the present reproduction of the German edition may tend to restrict the wide sale and use that it deserves.

Praktikum der Textilveredlung. O. Mecheels. (In German.) Ann Arbor, Michigan, Edwards Brothers, Inc., 1944. 380 pages. Price, $8.00.

(Reviewed by John H. Skinkle)

This book is one of those originally printed in Germany (1940), which have been reprinted during the war by authority of the Alien Property Custodian. As the title indicates, it covers the subject of textile processing in the form of procedures and experiments; it was apparently intended as a laboratory manual for students of textile chemistry and would be very useful in that capacity. The bleaching and dyeing of all the fibers are taken up, followed by the processing of mixtures, printing, and finishing.

The author's enthusiasms have, of course, crept into the book, which caused him to devote an undue amount of space to a few subjects, such as merizing, while certain other subjects, such as wool finishing, have been somewhat skimped. The sudden stops in the text to give details of testing technique are somewhat disconcerting and could have been avoided by combining them in a separate section. The chemical explanations and equations are at times absurdly elementary and at other times extremely advanced.

On the credit side of the picture, the book is extremely easy to follow, directions are sufficiently detailed but not boringly so, and the explanations and principles at the beginning of each section fill a want

which is not met in any textbook in the English language.

It is unfortunate that only German authorities and references were used.

1946 Classified Directory. 10th Ed. Association of Consulting Chemists and Chemical Engineers, Inc. New York, 1946. 88 pp.+xx. No charge.

The tenth edition of directory of members of the Association lists 88 consulting chemists and chemical engineers. A brief résumé of the experience and business and professional affiliations of the members is given. The principal fields of research and consulting work are outlined. 13 members are listed as active in the textile field.

ABSTRACTS

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A list of periodicals, the abbreviations used in references to articles, and the addresses of publishers of English language publications is given on page 84 of the February, 1946, issue.

ANALYSIS: TESTING: LABORATORY METHODS

★

Breaking Strength of Fabrics

Comparison of strip and grab breaking strength of two classes of upholstery fabrics. Bess V. Morrison and June C. Wilbur. *Rayon Text. Mo.* **27**, 361–3 (July 1946).

Breaking strengths by the strip and the grab methods were determined for 8 cotton damasks and 21 cotton tapestry fabrics. Analysis of the data reveals good correlation between the 2 methods. Regression equations are derived which relate strip and grab breaking strengths for these 2 classes of fabrics. J. F. Keating

Text. Research J. Nov. 1946

Test for Bleached Cotton

Schweitzer's reagent for identifying cotton goods that have been bleached, mercerized, or given similar treatment. Eliseo T. Huergo. *Industria y quím.* **8**, 48–51 (1946) (through *Chem. Abstr.* **40**, 5256[1] (Sept. 10, 1946)).

The tests used for detecting whether cotton fiber has been modified by processing are critically reviewed. The best results are obtained by treatment with Schweitzer's reagent and observation under the microscope. The preparation, conservation, and use of the reagent are described.

Text. Research J. Nov. 1946

Elastic Properties of Fibers

The elastic properties of textile fibers. Pierre Chevenard and Georges Champetier. *Compt. rend.* **222**, 954–7 (1946) (through *Chem. Abstr.* **40**, 5254[9] (Sept. 10, 1946)).

Measurements of the average slope (df/dl) of the stress (f)-elongation (l) curve for a small fixed cycle can be made with a *new microapp.* consisting of a dynamometer spring and a photorecorder. The instrument can be used with test pieces 2–150 mm. in length and is capable of stretching speeds of 6–300 mm./min. Data are presented for x as a function of f, where $x = [(df/dl) - (df/dl)_0]/(df/dl)_0$, and $(df/dl)_0$ is the slope at zero stress. For fully-drawn nylon, x is a linear function of f for all x values from 0 to 3. The same x values were observed for the 1st, 2nd, and 3rd cycles of elongation. For raw silk, x is a linear function of f from $x = 0$ to $x = 0.4$, and similar results were obtained on 1st, 2nd, or 3rd cycles. Ramie fibers gave different results on the 1st as compared to later cycles. For the later cycles, x was a linear function of f up to $x = 0.4$. Keratin did not show a linear x-f relationship. On passing the pseudoelastic limit, x decreased sharply. Hysteresis was observed with keratin at low stresses.

Text. Research J. Nov. 1946

Electron Micrographs of Fibers

Technique of electron-microscope investigation of fiber surfaces. Stanley F. Kern. *J. Polymer Sci.* **1**, 259–65 (Aug. 1946).

The technique of obtaining polystyrene silica replicas of surfaces and cross sections of fibers is described in detail. Electron micrographs of wool, cotton, and various types of rayon are shown.

Text. Research J. Nov. 1946 E. D. Klug

Abstract Reprints

The JOURNAL *is again offering to its subscribers reprints of the Abstracts and Book Reviews sections, printed on one side of the sheet so that the items may be clipped, pasted on cards, and filed for permanent reference. Subscription to this service for 1947 is $3.00. Orders for this special service should be mailed at once to Textile Research Institute, Inc., 10 East 40th Street, New York 16, N. Y.*

Identification of Fibers

The differentiation of fibers. K. Frische. *Textile-Ring* **1**, 26–7 (Sept. 1943) (through *Chem. Abstr.* **40**, 5569[1] (Sept. 20, 1946)).

Color reactions are listed for differentiation of wool, cotton, silk, linen, viscose rayon, cuprammonium rayon, acetate rayon, casein wool, ramie, and hemp.

Text. Research J. Nov. 1946

Analysis of Polymers by Ultraviolet Absorption

Comparison of ultraviolet absorption and chlorine analysis methods for composition of butadiene-*p*-chlorostyrene copolymers. E. J. Meehan, T. D. Parks, and H. A. Laitinen. *J. Polymer Sci.* **1**, 247–8 (Aug. 1946).

Analysis of 3 butadiene-*p*-chlorostyrene copolymers for *p*-chlorostyrene by ultraviolet absorption agreed well with those obtained by direct chlorine analysis (sodium fusion and amperometric titration on the chloride ion). The ultraviolet absorption method has an accuracy of 3–4%. E. D. Klug

Text. Research J. Nov. 1946

Testing Water-Repellent Fabrics

The quartermaster fights the weather. W. M. Lee. *Am. Dyestuff Reptr.* **35**, P72–6 (Feb. 11, 1946).

A general discussion of the problems involved in the evaluation for procurement of tentage and water-resistant clothing. Evaluation of fire-, water-, weather-, and mildew-resistant duck has been especially difficult, and the conclusion has been reached that one cannot predict with any degree of certainty its general outdoor performance from any series of laboratory tests practicable to run repeatedly. The study of the weathering of fabrics must consist of two phases: (1) accurate recording of the various factors of weather in a number of typical climatic areas and (2) a laboratory study of each of these effects, isolated, and applied to fabric in measured doses. Tests for acceptance of water-repellent fabrics follow the pattern: first, a spray rating as a screening test; second, 120 min. of wet abrasion; third, a series of 4 tests: dynamic equilibrium (rate of take-up of liquid under vigorous mechanical action), spray rating, Suter height, and air permeability. The Quartermaster Corps has, where possible, adopted the policy of carrying out extended evaluation tests, quantitatively related to real performance, on any treatment presented for consideration, and, on the basis of these tests, setting up approved lists of treatments; acceptance from within this list requires only examination by simplified laboratory tests. The dangers inherent in accelerated testing are discussed. Tentage-exposure and water-resistance studies as carried out at Camp Lee, Va., are described.

K. S. Campbell

Text. Research J. Nov. 1946

CHEMICAL AND PHYSICAL RESEARCH

★

Synthesis of Amino Acids

Synthetic amino acids. Wesley O. Fugate. *Interchem. Rev.* **5**, 3–11 (Spring 1946).

The most satisfactory methods of preparing amino acids are outlined. 24 references. E. N. Harvey, Jr.

Text. Research J. Nov. 1946

Anhydrides of Polyhydric Alcohols

The anhydrides of polyhydric alcohols. Part II. Derivatives of 1,2–5,6-dianhydro mannitol. L. F. Wiggins. *J. Chem. Soc.* **1946**, 384–8 (May 1946).

By the action of cold sodium methoxide on 1,6-dichloro-3,4-ethylidene mannitol the monoacetone and the monoethylidene derivatives of 1,2–5,6-dianhydromannitol have been obtained. These compounds were extremely reactive and suffered ring fission under mild alkaline or acid conditions. The constitutions of these compounds have been proved and some products of ring fission have been described. Author

Text. Research J. Nov. 1946

The anhydrides of polyhydric alcohols. Part III. Derivatives of 5,6-anhydro mannitol and sorbitol. L. F. Wiggins. *J. Chem. Soc.* **1946**, 388–90 (May 1946).

5,6-Anhydro-1,3–2,4-diethylidene sorbitol and 5,6-anhydro-1,2–3,4-diacetone mannitol have been prepared. These anhydro bodies readily suffer ring fission through the agency of ammonia, giving rise to 6-amino-1,3–2,4-diethylidene sorbitol and 6-amino-1,2–3,4-diacetone mannitol. Author

Text. Research J. Nov. 1946

The anhydrides of polyhydric alcohols. Part IV. The constitution of dianhydro sorbitol. R. Montgomery and L. F. Wiggins. *J. Chem. Soc.* **1946**, 390–3 (May 1946).

The constitution of dianhydro sorbitol (also known as isosorbide) is shown through its synthesis from 3,6-anhydroglucose and the synthesis of its dimethyl derivative from 3,6-anhydro-2,5-dimethyl glucofuranose to be that of 1,4–3,6-dianhydro sorbitol. Authors

Text. Research J. Nov. 1946

The anhydrides of polyhydric alcohols. Part V. 2,5-Diamino-1,4–3,6-dianhydro mannitol and sorbitol and their sulfanilamide derivatives. R. Montgomery and L. F. Wiggins. *J. Chem. Soc.* **1946**, 393–6 (May 1946).

By treatment of the 2,5-ditosyl derivatives of 1,4–3,6-dianhydro mannitol and sorbitol with methyl alcoholic ammonia the corresponding diamines have been obtained. These have been characterized by the formation of a series of well-defined salts and other derivatives. The sulfanilamide derivatives were found to be less active than sulfathiazole in routine bacteriostatic tests. Authors

Text. Research J. Nov. 1946

Absorption of Water by Cellulose

The hydrates of cellulose. P. H. Hermans and A. Weidinger. *J. Colloid Sci.* **1**, 185–93 (Mar. 1945).

It is shown from x-ray data that the formation of true hydrates plays a part in the process of moisture absorption in cellulose fibers. Crystalline hydrate *I* is formed when mercerized cellulose is exposed to water vapor and hence the latter, unlike native cellulose, exhibits intramicellar swelling. Crystalline hydrate *II* is formed when cellulose compounds containing water (alkali cellulose or cellulose xanthate) are decomposed at low temperature. The lattice constants for both hydrates are given. Hydrate *I* contains $\frac{1}{3}$ or $\frac{1}{2}$ molecule of water per glucose unit; hydrate *II* contains $1\frac{1}{3}$ or $1\frac{1}{2}$ molecules of water. In the amorphous part of the cellulose fiber both hydrates are formed if sufficient water is absorbed. E. D. Klug

Text. Research J. Nov. 1946

Optical properties of the system cellulose-water. P. H. Hermans, J. J. Hermans, and D. Vermaas. *J. Colloid Sci.* **1**, 251–60 (May 1946).

Measurements of the refractive index of moist isotropic model filaments (viscose rayon) are in agreement with Gladstone and Dale's rule for mixtures. This also applies to the 2 refractive indices of ramie and anisotropic model filaments (stretched viscose rayon) below approximately 15% regain. The results are interpreted to mean that in the absorption of water by cellulose an essentially homogeneous binary mixture of water and the amorphous part of the fiber (in which hydrate formation may play a role) is formed. Water absorption is not considered a surface action of a colloidal structure. E. D. Klug

Text. Research J. Nov 1946

Amino Esters of Cellulose

Cellulose acetate esters containing aminonitrogen. Thomas S. Gardner. *J. Polymer Sci.* **1**, 121–6 (Mar. 1946).

Cellulose acetate (substitution 2.06) was esterified in dioxane solution with the following N-acetylamino acids using chloroacetic anhydride as impelling agent and magnesium perchlorate as a catalyst: *dl*-α-alanine, β-alanine, α-aminoisobutyric, *d*-glutamic, and *p*-aminobenzoic acid. The estimated extent of esterification ranged from 0.2 to 0.8 mole of amino acid per anhydroglucose unit. Many of these esters dyed well with a typical wool dye. Cellulose acetate metanilate was prepared by use of the aminosulfoacid chloride. Attempts to prepare 6-aminocellulose by reacting ammonia or sodamide with *p*-toluenesulfonyl (tosyl) ester of cellulose acetate or the 6-iodotosylcellulose acetate gave badly degraded products containing only traces of nitrogen. E. D. Klug

Text. Research J. Nov. 1946

Bacterial Decomposition of Cellulose

Carbon dioxide as an essential factor in the bacterial decomposition of cellulose. A. S. Perlin and M. Michaelis. *Science* **103**, 673 (May 31, 1946).

The decomposition of cellulose by a mixed culture of *Vibrio perimastrix* and another unidentified bacterium has been found to take place only in the presence of carbon dioxide. The only products of the decomposition found were traces of unidentified acids. H. W. Theller

Text. Research J. Nov. 1946

Cellulose Fibrillae

Fibrillar structure of cellulose of bacterial and animal origin. M. Aschner and S. Hestrin. *Nature* **157**, 659 (May 1946).

Microscopical methods for examining cellulose of bacterial and animal origin, and observations made using these methods are described. Both types of cellulose show the presence of microscopic fibrils. Observations are reported which support the conception that the fibril is formed by an extracellular process of cellulose crystallization, rather than by a hairlike outgrowth of the cell wall. R. W. Eyler

Text. Research J. Nov. 1946

Fractionation of Cellulose

Fractionation of cellulose. O. A. Battista and Wayne A. Sisson. *J. Am. Chem. Soc.* **68**, 915 (May 1946).

In studying the fractionation of cellulose, cuprammonium hydroxide is considered the best solvent. The choice of the precipitant is important. Fractional precipitation with 5% aqueous NaK tartrate showed little resolution. With acetone fractions, average basic degrees of polymerization from 535 to 142 were obtained; with isopropyl alcohol fractions the values were 615 to 132. The material used was rayon tire yarn of average D.P. 490.

A. R. Macormac

Text. Research J. Nov. 1946

Cellulose Gels

Submicroscopic structure of cellulose gels. A. Frey-Wyssling and K. Mühlethaler. *J. Polymer Sci.* **1**, 172–4 (May 1946).

Electron micrographs illustrating the crystallization of submicroscopic cellular strands from multimolecular cellulose films of *Bacterium xylinoides Henneberg* are shown. The cellulose threads 200 Å. in diameter are said to be embedded in growing film which is less than 100 Å. thick. Orientation of chains in the direction of stretch is visible. E. D. Klug

Text. Research J. Nov. 1946

Hydrolysis of Cellulose

The solution and hydrolysis of cellulose in concentrated zinc chloride solution. Hannes Sihtola. *Finnish Paper Timber J.* **26**, 287–93 (in English, 287–8) (1944); cf. *C.A.* **38**, 6091[4] (through *Chem. Abstr.* **40**, 4879[6] (Aug. 20, 1946)).

Solutions of 258.1, 267.1, and 303.5 mg./l. of cellulose in 65% $ZnCl_2$ (d. 1.851, η_0 19.95 pure) showed viscosities at 20° of 26.25, 26.43, and 27.23 centipoises, respectively, resulting in a K_m value in the Staudinger equation of 18.73×10^{-4}.

The molecular weight of the cellulose in solution was calculated to be 87,420. With this M value, $K_m \times 10^4$ values were found at 30°, 40°, 50°, and 60° to be 17.62, 16.72, 15.96, and 15.47, respectively. Extrapolation to 70° and 80° gave additional values of 15.05 and 14.71 at these temperatures. The addition of varying amounts of 0.01 N HCl to the $ZnCl_2$-cellulose solutions, with heating at 60°, 70°, or 80°, caused little change in the energy of activation (E) or the activation constant (A) until 0.2–0.75 cc. of free excess HCl is present, at which point E falls from 39,600 to 27,400, and A falls from 1.1×10^{19} to 3.2×10^{12}. It is suggested that an addition compound $(C_6H_{10}O_5 \cdot ZnCl_2 \cdot 8H_2O)_n$ is initially formed, which changes to the compound $(C_6H_{10}O_5 \cdot HCl \cdot 4H_2O)_n$ as soon as the solution contains free HCl. The hydrolytic cleavage velocity of the cane-sugar molecule was calculated to be approximately 10^4 times greater than that of single bonds in the molecule chain of cellulose.

Text. Research J. Nov. 1946

Oxidation of Cellulose

Transformations of the macromolecule of cellulose. V. I. Ivanov and O. P. Golova. *Bull. acad. sci. U.R.S.S., Classe sci. chim.* **1945**, 385–7 (through *Chem. Abstr.* **40**, 4879[5] (Aug. 20, 1946)).

Depending on the nature of the medium in which the oxidation of cellulose is carried out, derivatives can be obtained of equal N content but of sharply different fluidity, solubility, and mechanical properties. The significance of these facts is discussed.

Text. Research J. Nov. 1946

Production of Cellulose

The complete utilization of wood fiber as raw material in relation to the qualitative improvement of viscose cellulose. R. E. Dörr. *Finnish Paper Timber J.* **26**, 19–23, 37–40, 49–53 (1944) (in German) (through *Chem. Abstr.* **40**, 4880[1] (Aug. 20, 1946)).

Pine wood and various annuals (rye, wheat, and oat straw) containing 40–45% utilizable cellulose can be converted by the sulfate process and a preliminary hydrolysis into a high-quality textile fiber or cellulose raw material. The preliminary hydrolysis is carried out with dilute H_2SO_4 at elevated temperatures, and the α-cellulose content is increased in the case of wood from 88–89% to 94–97%. A sample of straw preliminarily hydrolyzed at 130° for 3 hrs. with 0.5% H_2SO_4 gave 68.8% cellulose, of which 96.5% was α-cellulose. SO_2 solutions (5%) can be used in place of H_2SO_4. The sugar solutions obtained as hydrolyzates can be used for the production of alcohol by fermentation and distillation.

Text. Research J. Nov. 1946

Elastic Properties of Cellulose Acetate

The effect of volume sorption on the mechanical properties of polymers. S. N. Zhurkov. *Compt. rend. acad. sci. U.R.S.S.* **49**, 198–201 (1945) (English summary) (through *Chem. Abstr.* **40**, 4278[1] (Aug. 10, 1946)).

The effect of absorption of methanol, ethanol, butanol, acetone, and water on the elastic properties of cellulose acetate (28% free hydroxyl) fibers 20 μ in diameter and 1 m. long was determined. The quantity of vapor absorbed was measured by means of a spring balance having a quartz spiral. Hooke's modulus of elasticity diminishes in proportion to the amount of material absorbed. The sorption of equimolecular amounts of the above vapors causes the same decrease in the elasticity modulus. The observations obey the following equation: $E = E_0 - K(C/M)$, where E and E_0 are the elasticity moduli of the fiber in the dry and swollen states, respectively, K is a constant equal to 1.37 to 1.4 for the above solvents, taking $M = 2 \times 18$ for H_2O and (C/M) is the molar concentration of absorbate in the fiber. The mean value of E is 1.38×10^3 kg./sq. mm., when (C/M) is expressed in g.-molecules per 100 g. cellulose acetate.

Text. Research J. Nov. 1946

Cotton Substantive Dyes

Relationship between "substantivity" and constitution of compounds that are cotton substantives. II. Bernd Eistert. *Ann.* **556**, 91–102 (1944) (in German) (through *Bull. Inst. Paper Chem.* **16**, 497 (July 1946)).

The properties of cotton substantive dyes depend on the presence of long conjugated systems or at least on the possibility of forming such systems. Conjugation involves a planar arrangement of the atoms in the molecule, and cellulose appears to retain planar molecules more readily than nonplanar ones. Substantivity may actually be used (with reservation) as a criterion as to whether or not a compound has a planar structure. The experimental part of the article involves the preparation of dyes and dye intermediates, some of which manifest an affinity for cotton. 22 references.

Text. Research J. Nov. 1946

Cotton Wax

Cotton wax properties and constituents. W. H. Tonn, Jr., and E. P. Schoch. *Ind. Eng. Chem.* **38**, 413–15 (Apr. 1946).

Twenty-five lbs. of cotton wax were obtained by the extraction of 10 bales of cotton with hot benzene. The yield of wax was 0.2% to 0.7%. It was about the consistency of beeswax, dark-colored, and with a disagreeable odor. The color and odor can be partly eliminated by a treatment with activated carbon and/or fuller's earth. Chlorine compounds or hydrogen peroxide may also be used. The resulting wax varies from a faint yellow to an orange. It blends well with other waxes and resins. The constants of the crude wax are: melting point 68–71°C, specific gravity (15/15°C) 0.959, saponification value (mg. KOH/g.) 70.6, acid value (mg. KOH/g.) 32.0, acetyl value (mg. KOH/g.) 73.1, iodine number (g./100 g.) 24.5, fatty acid 25%, unsaponifiables 69%, Hehner value 100%, Reichert-Meissl value 0 ml., inert matter 6%. The fatty acids consisted of 24% saturated and 1%

unsaturated acids. The unsaponifiables were 52% alcohols, 10% sterols, and 7% hydrocarbons.

A. R. Macormac

Text. Research J. Nov. 1946

Solubility (of cotton wax) in common solvents. W. H. Tonn, Jr., and E. P. Schoch. *Ind. Eng. Chem.* **38**, 415–16 (Apr. 1946).

Curves are given for the solubility of cotton wax in benzene, toluene, xylene, turpentine, carbon tetrachloride, carbon disulfide, chloroform, Skelly solvent C, ethyl acetate, acetone, diethyl ether, glacial acetic acid, and methyl, ethyl, *n*-propyl, *n*-butyl, isoamyl and tert. butyl alcohols between 0 and 70°C. These solvents form 2 groups. Group *I* consists of the first 8 in which cotton wax is readily soluble (more than 20 g./100 g. at 55°C). The others are in group *II* in which the cotton wax is difficultly soluble. The solvents in the latter group seem to exert some selectivity with the highly colored, high-melting, resinous fractions being less soluble.

A. R. Macormac

Text. Research J. Nov. 1946

Isopropyl alcohol in cotton wax determination. James H. Kettering. *Ind. Eng. Chem., Anal. Ed.* **18**, 275 (Apr. 1946).

Data are presented to indicate that isopropyl alcohol can be used to replace ethyl alcohol in the extraction of the wax in cotton by the Conrad method. (*Ind. Eng. Chem., Anal. Ed.* **16**, 745–8 (1944)).

A. R. Macormac

Text. Research J. Nov. 1946

Photochemical Decomposition

The photochemical decomposition of cellulose acetate-butyrate. R. L. Tichenor. *J. Polymer Sci.* **1**, 217–24 (May 1946).

Irradiation of cellulose acetate-butyrate with ultraviolet light caused a cleavage of the polymer chain so that the viscometric average molecular weight is decreased. Wave lengths shorter than 3500 Å. are most effective; longer wave lengths are less active. Though the acyl content and carbon-hydrogen content of irradiated products were not changed appreciably, solubility in the usual solvents decreased, but addition of HCl to some of the solvents improved solubility. The rate of degradation was not accelerated greatly by common metallic impurities or possible decomposition products such as acetic acid, butyric acid, cellobiose octa-acetate, and others. Irradiation of several fractions of a fractionated acetate-butyrate showed that the rate of degradation is independent of the average molecular weight.

Text. Research J. Nov. 1946 E. D. Klug

Electron Microscope

A study of distortion in electron microscope projection lenses. James Hillier. *J. Applied Phys.* **17**, 411–19 (June 1946).

Distortion in the projection lenses of an electron microscope can be demonstrated, and relatively slight aberration of a projection lens can cause marked distortion of the image. The effect of this distortion upon the measurement of particle-size distribution, for example, is appreciable. Both theory and experiment show that it is possible to design a projection-lens system which eliminates to a large degree the distortion due to spherical aberration. T. J. Dietz

Text. Research J. Nov. 1946

Fatigue Failure

Fatigue failure of rayon tire cord. R. C. Waller and W. E. Roseveare. *J. Applied Phys.* **17**, 482–91 (June 1946).

Experimental fatigue failure of tire cord is discussed in terms of (1) magnitude and frequency of the cyclic stroke, (2) average load, (3) minimum load, (4) temperature, and (5) humidity. Results obtained from experiments in which each of the above parameters was treated separately indicate that the relative fatigue ratings of samples of rayon tire cord depend not only upon the above variables but also upon the modulus and twist structure of the cords. Fatigue failure is interpreted as the result of the breaking of a critical number of filaments within a given volume, thus producing a weak spot in the cord. T. J. Dietz

Text. Research J. Nov. 1946

Contact Angle of Films

The contact angle between water and a monolayer of egg albumin on glass as a function of film pressure. George Jura and William D. Harkins. *J. Colloid Sci.* **1**, 137–40 (Mar. 1946).

The contact angles of water against monolayers of egg albumin deposited on glass were found to vary from 23.8° to 56.4° as the film pressure of the egg albumin on water, from which it was deposited on the slide, varied from 8.8 to 23.0 dyne cm^{-1}. The contact angle of water against the protein film on the glass was found to be a linear function of the film pressure of the film on water. The results indicate that at no pressure at which the film is stable does the outer surface of the monolayer, after transference to the glass, consist entirely of nonpolar groups.

Text. Research J. Nov. 1946 Authors

Oiling of Jute

The oiling of jute. Part I. Comparative fibre-lubricating properties of oil mixtures as studied by fibre length analysis of card slivers. W. G. Macmillan and M. K. Sen. *J. Text. Inst.* **37**, T141–50 (June 1946).

Approximately 20,000 measurements of fiber length were carried out, in order to find a method of fiber length analysis for jute slivers. It has been found that the pinch method and the tuft method are not suitable for this purpose—the former owing to indefinite length bias, and the latter on account of unavoidable breakages of fibers in sampling. The draw method has been shown to give the best results, and, from statistical considerations, it has been found that the sliver should be divided into 16 zones, samples being drawn from each zone. About 1,000 measurements for a set are adequate. For any sample of sliver, 3 sets of measure-

ments should be taken, and the mean distribution of length proportions determined. Should there be any wide differences in the length proportions found in the 3 sets, a second 3 sets should be taken, and the mean of 6 sets then accepted as representative. On applying this method of analysis to various card slivers, it has been found that the lubricating power of mineral oil is increased by the addition of certain vegetable oils, of which castor and groundnut oils are the most effective. The mixture should contain 25% by volume of the vegetable oil.

Text. Research J. Nov. 1946 Authors

Latex

The coagulation of latex. William Seifriz. *Science* **102**, 378–80 (Oct. 12, 1945).

From an electrophoretic study of latex, involving the determination of mobility rates and isoelectric points, it is concluded that the surface of latex particles is not completely proteinaceous, but probably contains some of the same hydrocarbon which constitutes the core of the latex globule.

Text. Research J. Nov. 1946 H. W. Theller

Moisture Relations of Textiles

Moisture adsorption of textile yarns at low temperatures. Robert C. Darling and Harwood S. Belding. *Ind. Eng. Chem.* **38**, 524–9 (May 1946).

Equilibrium moisture content of wool at 0°F and 55, 70, and 88% relative humidity was 13.0, 18.5, and 21.4%; for raw cotton, 6.8, 9.6, and 11.6%; for purified cotton, 6.6, 9.8, and 11.8%; for viscose rayon, 11.9, 17.4, and 21.4%; for acetate rayon, 6.5, 9.7, and 12.3%. Determinations were also made at −20°F and 69% R.H. and 40°F at 50% and 90% R.H. The values obtained together with others from the literature indicate that at any constant relative humidity there is a high point between 0° and 40°F and that less water is bound at both lower and higher temperatures. The curve of log equilibrium moisture against $1/T$ is not linear over a temperature range −20°F to 160°F, but rather is flat between 0° and 40°F, and has a negative slope at higher and a positive slope at lower temperatures. The curves for heat of adsorption have a similar but inverted shape to that of the moisture-content curves.

A. R. Macormac

Text. Research J. Nov. 1946

Periodic Acid Oxidations

Determining the oxygen used in the oxidation of carbohydrate by periodic acid in sulfuric acid. Eskil Hultin. *Svensk Kem. Tids.* **57**, 300–2 (1945) (in German) (through *Chem. Abstr.* **40**, 3728[9] (July 10, 1946)).

The sugar solution in dilute H_2SO_4 was treated with an equal volume 0.1*M* HIO_4 and placed in a thermostat at 50°. At specified time intervals the sample was cooled, NaI solution added, and the free iodine titrated with standard $Na_2S_2O_3$, from which the 0 used was calculated. The procedure follows very closely that published by Ahlborg (*C.A.* **38**, 4254[8]). The 0 used per mol. sugar agrees very well with that calculated if corrected for secondary oxidation after the main oxidation is completed. This correction item is obtained from a graph which is not given. For maltose (calculated 0 consumed per mol. 10.0) are given below, respectively, the value found by titration, the correction applied, and the corrected value: at end of 1 hr., 9.96, 0.038, 9.84; end of 5 hrs., 10.69, 0.157, 9.95. For trehalose (calculated 0 per mol. 4.0): at end of 1 hr., 3.84, 0.025, 3.81; end of 8 hrs., 4.27, 0.274, 4.00.

Text. Research J. Nov. 1946

Pectin

Characterization of pectin. Claude H. Hills and Rudolph Speiser. *Science* **103**, 166–7 (Feb. 8, 1946).

Pectin is composed principally of anhydrogalacturonic acid residues, partially methylesterified and linked together to form the long chain which is responsible for the characteristic properties of pectin—gelation, film formation, and high viscosity in dilute solution. Non-galacturonide materials such as galactan and araban may constitute $\frac{1}{3}$ or more of the weight of the pectin, but these may be considered to act mainly as diluents. Upon acid de-esterification the methyl ester groups and the nongalacturonide materials are removed at approximately the same rate, while in enzyme de-esterification the nongalacturonide content is reduced only slightly. These products may differ considerably in properties, and yet this difference might not be fully reflected by the usual characterization based on methoxyl content and neutralization equivalent, since the pectins contain different amounts of diluent. It is recommended that the galacturonide content and degree of esterification of the galacturonide chain be used in the characterization of such pectins.

Text. Research J. Nov. 1946 H. W. Theller

Agglomeration of Pigment Particles

Factors which cause or prevent agglomeration of pigment particles. Rhode Island Section A.A.T.C.C. *Am. Dyestuff Reptr.* **35**, P3–12 (Jan. 14, 1946).

An investigation was made of the particle agglomeration resulting in reduced color yield in vat printing. Electrolytes with divalent or trivalent cations, substances of dehydrating nature which tend to disturb the vehicle (water) envelope around the color particle, and certain properties related to the colloidal nature of the thickening agent used are shown to be potential causes of pigment-particle agglomeration. Dispersion may sometimes be improved by addition of very finely divided inert substances such as silica.

Text. Research J. Nov. 1946 K. S. Campbell

Polymerization Catalysts

Preparation and properties of rubberlike high polymers. I. Polymerization of dienes and vinyl compounds in bulk. C. Koningsberger and G. Salmon. *J. Polymer Sci.* **1**, 200–16 (May 1946).

Diazoaminobenzene acts as a mild catalyst for the polymerization of

butadiene and dimethylbutadiene. The rate of uncatalyzed dimerization of butadiene is great and interferes with the polymerization. The catalytic effect of benzoyl peroxide on butadiene and dimethylbutadiene is 100 to 1,000 times greater than that of diazoaminobenzene. Diazoaminobenzene has about the same catalytic effect on the polymerization of styrene and acrylonitrile as on that of the dienes. The catalytic effect of benzoyl peroxide on diene polymerization is 10,000 to 100,000 times less than on vinyl compounds. This is explained on the basis of benzoyl peroxide consumption in oxidizing dienes and their polymers. The properties of the polymers are discussed.

Text. Research J. Nov. 1946 E. D. Klug

Elastic Deformation of Polymers

Elastic deformation and molecular weight in polyisobutylene. John Rehner, Jr. *J. Polymer Sci.* **1**, 225–8 (May 1946).

The rate of compression of molded specimens of polyisobutylene molded at 141°C was measured with a Williams plastometer. By using a high compressive load (15 kg.) and limiting readings to an interval of 1 min., the viscous component of deformation was rendered negligible. The slopes of the straight lines obtained by plotting deformation against the logarithm of time were approximately proportional to the reciprocal of the viscometric average molecular weights. The molding operation causes a loss of 5 to 30% in the average molecular weights. E. D. Klug

Text. Research J. Nov. 1946

Hardening of Polymers

The mechanism of hardening of polymers. S. N. Zhurkov. *Trudy Konferentsii Vysokomolekulyar. Soedineniyam, Akad. Nauk S.S.S.R., Otdel, Khim. Nauk i Otdel. Fiz.-Mat. Nauk* **2**, 66–76 (1944) (Pub. 1945) (through *Chem. Abstr.* **40**, 3718[8] (July 10, 1946)).

When polar polymers absorb the vapors of volatile solvents, the temperature interval of hardening decreases directly proportionally to the number of mols. of solvent absorbed. In nonpolar polymers, the decrease depends not only on the number of solvent molecules but also on their size and configuration. It is assumed that hardening depends on formation of a network of polymer chains held together by intermolecular bonds. In polar polymers, these bonds are polar and each mol. of solvent blocks 1 bond. In nonpolar polymers the binding forces are not so uniform and 1 mol. of solvent may block several intermolecular bonds. Transition from the hard to the rubbery state in polymers on heating depends on partial breakage of the network. Mathematical calculations confirm this theory.

Text. Research J. Nov. 1946

Interaction of Polymers and Liquids

The determination of polymer-liquid interaction by swelling measurements. Paul Doty and Helen S. Zable. *J. Polymer Sci.* **1**, 90–101 (Mar. 1946).

The interaction of polymers and liquids can be fairly well characterized by the value of the quantity μ, commonly used in thermodynamics of polymer solutions and usually evaluated from osmotic pressure measurements. For a cross-linked polymer it is also necessary to determine the swelling volume. The swelling volume and μ value for cross-linked polyvinyl chloride was determined in 50 different liquids at room temperature. The variation of μ with molecular weight of a series of homologous dialkyl phthalates is plotted. E. D. Klug

Text. Research J. Nov. 1946

Properties of Polymers

Effect of the volume sorption of vapors on the solidification temperature of polymers. S. N. Zhurkov and R. I. Lerman. *Compt. rend. acad. sci. U.R.S.S.* **47**, 106–9; *Doklady Akad. Nauk S.S.S.R.* **47**, 109–12 (1945) (through *Chem. Abstr.* **40**, 4277[8] (Aug. 10, 1946)).

Polymers exhibit a fairly narrow temperature range of solidification, within which the hardness decreases rapidly with increasing temperature. Characteristic S-shaped curves were obtained by plotting the log of the high elastic modulus E vs. temperature. When the polymers are swollen in the vapors of organic solvents they give identically shaped log-E-vs.-temperature curves, but at a lower temperature. It is found for 4 polymers, butadiene-acrylonitrile (*I*), polymethylacrylate (*II*), butadiene rubber (*III*), and polyisobutylene (*IV*), that the lowering in temperature of solidification ΔT after swelling with any of 30 different solvents is a linear function of the number of sorbed molecules n. The relation $\Delta T = kn$ holds strictly for *I* and *II*, k being the same for a number of polar solvents; with *III* and *IV*, k varies with the solvent. The phenomena are regarded as prototypes of the action of plasticizers. The change in properties induced in *I* and *II* by polar solvents is due to the interaction of the solvent with the function groups of the polymer; 1 molecule of solvent interacts with only 1 group. With *III* and *IV*, the solvent molecule interacts with the polymer at several undefined points, and the effectiveness increases with molecule size.

Text. Research J. Nov. 1946

Supersonic Treatment of Fibers

Electron-microscopic investigations of cellulose fibers after supersonic treatment. K. Wuhrmann, A. Heuberger, and K. Mühlethaler. *Experientia* **2**, 105–7 (1946) (in German) (through *Chem. Abstr.* **40**, 4219[7] (July 20, 1946)).

Present methods of preparation of cellulose fibers for electron-microscopic investigations tend to modify the original structure. Consequently interpretation is very difficult and results disagree with those obtained by other methods. It was found that exposure of cellulose fibers such as ramie, hemp, cotton, to intense supersonic fields for from 3 to 10 min. will yield extraordinarily fine fibrils without structural modification. Fibers barely observable microscopically are fur-

ther resolved under the electron microscope to within 60–70 Å. A photomicrograph of ramie, hemp, and flax after 10 min. supersonic treatment and an electron-microscopic photograph (×14,000) of ramie and hemp are shown. There is no uniform fiber size and dimensions are solely a function of the intensity of treatment. No preferential cleavage planes are apparent. The length of the finest mol. chain is 100 times the diameter and the impression is gained that there is no clearly defined end within the fibers. Diameters determined by means of x-rays should be considered merely as maximum values of a flat frequency curve which includes all possible values from a single chain to bundles having diameters far above 100 Å.

Text. Research J. Nov. 1946

Silicone Resins

Preparation, purification and polymerization of diethyl silicon dichloride. Turner Alfrey, Francis J. Honn, and H. Mark. *J. Polymer Sci.* **1**, 102–20 (Mar. 1946).

Diethyl silicon dichloride, prepared from silicon tetrachloride by the Grignard synthesis, was purified to various degrees by distillation, triple distillation, and triple distillation plus crystallization. Hydrolysis to diethylsilicanediol at temperatures from 5° to 100°C gave products of the same cryoscopic molecular weight. With products hydrolyzed at 5°C, the cryoscopic molecular weight and intrinsic viscosity decreased with increase in the extent of purification. There are indications that the chain length of the polymers obtained by heating the hydrolyzed monomers increases with the purity of the monomers. Phosphorus pentoxide not only acts as a dehydrating agent, accelerating condensation, but actually enters the polymer structure. E. D. Klug

Text. Research J. Nov. 1946

Dynamic Characteristics of Rubber

Dynamic characteristics of rubber supports from vibration table data. Ernest G. Chilton. *J. Applied Phys.* **17**, 492–5 (June 1946).

Measurements of the vibration of a free mass which is isolated by a rubber support from a surface vibrating at constant amplitude permit calculations of the dynamic characteristics of the support. This method permits high loadings and the application of considerable force. Author

Text. Research J. Nov. 1946

Sorption Chemistry

Survey of sorption chemistry. Edmund N. Harvey, Jr. *Interchem. Rev.* **4**, 95–110 (Winter 1945).

A general review of adsorption phenomena including brief discussions of the apparatus used, types of sorption encountered, methods of presenting the data and their significance, theories of sorption chemistry, adsorption from solution, chromatographic analysis, and types of commercial adsorbents. Correlations of adsorption effects observed with structure of adsorbents and with nature of adsorbed substances are emphasized. Author

Text. Research J. Nov. 1946

Enzymatic Hydrolysis of Starch

The isolation of levoglucosan from the enzymic hydrolysates of waxy corn starch. Edna M. Montgomery and G. E. Hilbert. *J. Am. Chem. Soc.* **68**, 916 (May 1946).

Waxy corn starch has been subjected to the consecutive action of β-amylase, α-amylase, and β-amylase and an amylase from *Aspergillus oryzae*. Various dextrines were separated at each stage. The final product contained levoglucosan.

A. R. Macormac

Text. Research J. Nov. 1946

Nitration of Starch

Nitration of starches with nitrogen pentoxide in the presence of sodium fluoride. G. V. Caesar and Max Goldfrank. *J. Am. Chem. Soc.* **68**, 372–5 (Mar. 1946).

Details of a laboratory method for nitrating corn and potato starches, thin-boiling corn starches, and corn dextrines are given. Complete nitration required a ratio of 3 to 5 N_2O_5 to 1 starch. The temperature was maintained below 16–18°C. The time for corn starch and dextrines was 20 min. and for potato, 30–60 min. The powdered starch (50 g.) was added to 150–250 g. N_2O_5 in 1,500 ml. $CHCl_3$ at 0°C. The nitrated product was washed with $CHCl_3$ and hot H_2O, then stabilized by boiling for 3 hrs. in H_2O neutralized with dilute NH_4OH. Results are also given for corn and potato amylose (unbranched portion) and corn and potato amylopectin (branched portion). A laboratory method for the preparation of N_2O_5 mixed with N_2O_4 is given. The HNO_3 (a byproduct of the reaction) is removed by the use of NaF which forms $NaF-HNO_3$ because of hydrogen bonding of the F. The degree of nitration can be varied. Since low temperature, low concentration of HNO_3, and anhydrous conditions can be maintained, it is believed that little degradation takes place and this method may be widely useful in the study of the structures of polysaccharides.

A. R. Macormac

Text. Research J. Nov. 1946

Dynamic Tensile Tests

Dynamic tensile tests of parachute webbing. Ambrose H. Stang, Martin Greenspan, and Sanford B. Newman. *J. Research Natl. Bur. Standards* **36**, 411–19 + 3 pp. photos (Apr. 1946).

Dynamic-load-stretch and stretch-energy data were obtained for two types of nylon and one type of cotton parachute webbing. These data were compared with similar data obtained from static tensile tests of the materials. The dynamic and static breaking strengths of the webbing were also obtained. The nylon specimens showed a reduced strength, stretch, and capacity for energy absorption under dynamic loading as compared with static loading. The cotton specimens showed under dynamic loading about the same strength, reduced stretch, and increased energy absorption. The energy absorbed by

the broken nylon specimens was more than three times that of the broken cotton specimens. Authors
Text. Research J. Nov. 1946

Viscose Solutions

Factors affecting the filterability of viscose solutions. Risto Vuori. *Finnish Paper Timber J.* **27**, 376–7 (English summary, 376) (1945) (through *Chem. Abstr.* **40**, 4879[9] (Aug. 20, 1946)).

Differences in the degree of polymerization of viscose solutions and that of the thick, heavy viscose removed from clogged filters indicated that uniformity in the degree of polymerization was of critical importance for the filtration process. No relationship was found between the filterability of the viscose and other characteristics of the cellulose, such as α-cellulose, alkali solubility, ash, resin content, Cu number, etc.
Text. Research J. Nov. 1946

Effectiveness of Wetting Agents

Constitution and effectiveness of wetting agents. Ernst Götte. *Die Chemie* **57**, 67–70 (1944) (through *Chem. Abstr.* **40**, 4541[9] (Aug. 10, 1946)).

A complete classification of soaps (wetting agents) is presented. Within a homologous series the wetting action is dependent on the state of solution and reaches an optimum value at a definite ratio of the hydrophobic to hydrophilic component in the molecule. The state of solution can be strongly influenced by electrolytes. The introduction of a second hydrophilic group into the molecule lowers the effectiveness greatly or makes the agent ineffective. The wetting power is greatly improved if the hydrocarbon chain in the hydrophobic part is branched and if the hydrophilic group is in a more or less central position. 19 references.
Text. Research J. Nov. 1946

Industrial Use of Wetting Agents

The industrial use of surface-active agents. Robert R. Ackley. *Ann. N. Y. Acad. Sci.* **46**, 511–29 (1946) (through *Chem. Abstr.* **40**, 4542[1] (Aug. 10, 1946)).

Simple determinations of wetting time, tensions, and foaming are usually not directly applicable to industrial applications because of increased number of components or complicated and dynamic conditions. Choice of wetting agent should be made not only on the basis of time, but also on extent of wetting required, effects of repeated use of solutions, temperature, age of solutions, concentration, pH, and electrolytes, including hardness of water. The bearing of physical and chemical properties on industrial applications is briefly discussed.
Text. Research J. Nov. 1946

Cell Structure of Wool

Structure of the cuticle of wool. E. H. Mercer and A. L. G. Rees. *Nature* **157**, 589–90 (May 1946).

Studies using electron microscopy and electron diffraction are reported. Component structures of cuticle cells of wool different in their appearance and their resistance to chemical and enzymic attack were distinguished. One smooth, featureless surface layer is readily removed by tryptic digestion and is attacked preferentially by chemical reagents, although in not so discriminating a manner as by enzymes. The similarity of this material and the intercellular cement is pointed out. The subsurface component is resistant to tryptic digestion and exhibits an uneven pitted surface. The significance of these observations in preventing shrinkage of woolens is discussed.
Text. Research J. Nov. 1946 R. W. Eyler

Felting of Wool

A chemical treatment of wool which increases its rate of felting. Martin R. Freney and P. Harris. *Nature* **157**, 664 (May 1946).

Shrinkages resulting from treatment of wool with benzoyl chloride in petroleum ether, followed by ammonium hydroxide, are discussed. Data are given showing that benzoylation causes the rate of shrinkage to increase. An increase of doubtful significance was obtained by treating the wool with acetyl chloride under similar conditions.
Text. Research J. Nov. 1946 R. W. Eyler

Immunization of Wool

Use of polymers to immunize wool against acid dyes. M. Lipson and J. B. Speakman. *Nature* **157**, 736 (June 1946).

Treatment of wool with ferrous ammonium sulfate, methacrylic acid, and hydrogen peroxide under the influence of heat is shown to result in resistance of the wool to acid dyes. It is suggested that the effect is not due solely to the acidity of the polymer, but that the reduction of the rate of diffusion of the dye into the fibers by the polymer is a factor. R. W. Eyler
Text. Research J. Nov. 1946

Resin Treatments for Wool

Formation of polymers in textile fibers. M. Lipson and J. B. Speakman. *Nature* **157**, 590 (May 1946).

Results obtained by treating wool with water and methyl methacrylate or acrylonitrile under the influence of heat and in the presence of ferrous sulfate or hydrogen peroxide or both are described. Iron alone was found to promote polymerization of methyl methacrylate; however, the reaction is more rapid in the presence of hydrogen peroxide. The latter was found to be essential for the polymerization of acrylonitrile. Data are given illustrating the increase in weight and the shrinkage resulting from the formation of polymers. R. W. Eyler
Text. Research J. Nov. 1946

BLEACHING: DYEING: FINISHING

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Dye Absorption

Fundamentals of dye absorption. S. M. Neale. *J. Colloid Sci.* 1, 371–9 (July 1946).

A review of the mechanism of dye absorption. The factors affecting

the diffusion of a direct dye into cellulose are the dye concentration, the temperature, and the concentration of added sodium chloride. The effect of the salt is to decrease the negative potential of the cotton and therefore to decrease its repulsion of the negatively charged dye anions. The same mechanism explains the effect of salt on the absorption of acid dyes by wool. There is no need to assume aggregation as a major factor in the behavior of dyes. Emf. measurements in concentration cells with dyed cellophane membranes and NaCl are in good agreement with an equation deduced on the assumption that "absorbed dye ions, together with mobile cations and anions of the dye and of the added electrolyte, are in an equipotential region consisting of the cellulose with its imbibed water."

Text. Research J. Nov. 1946 E. D. Klug

Dyeing Mohair-Rayon Blends

Dyeing mohair and rayon mixture cloths. Anon. *Text. Recorder* **64**, 52 (Aug. 1946).

Difficulties are described and solutions suggested, particularly for fabrics containing rayon waste in which some acetate is present.

Text. Research J. Nov. 1946 J. F. Keating

pH Control in Dyeing

pH control in dyeing processes. E. I. Noble. *J. Soc. Dyers and Colourists* **61**, 328–33 (Dec. 1945).

The buffering action of phosphoric acid and phosphates is discussed and the use of these materials in controlling pH in pretreatments and in dyeing processes is described. All chrome dyes and acid dyes may be dyed successfully with the aid of suitable mixtures of phosphoric acid and ammonia or mono-ammonium phosphate. K. S. Campbell

Text. Research J. Nov. 1946

Water Absorption of Rayon

Water absorption in regenerated cellulose rayons. Anon. *Silk and Rayon* **20**, 986 (Aug. 1946).

A review of formaldehyde treatments is given. J. F. Keating

Text. Research J. Nov. 1946

FIBERS: YARNS: FABRICS: MECHANICAL PROCESSES

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Bonded Webs

Unspun cotton. Ernest Stewart. *Mfrs.' Record* **115**, 44–5, 72 (1946) (through *Chem. Abstr.* **40**, 4890^6 (Aug. 20, 1946)).

Cotton fibers are cleaned, combed into mats, treated with a liquid plastic as a binder, and then the fibers are sent through rollers from which emerges unspun cotton cloth. Various applications of the new product are described.

Text. Research J. Nov. 1946

Deterioration of Dyed Fabrics

How different types of dyestuffs affect the rate of deterioration of cloth exposed to weather. Southeastern Section A.A.T.C.C. *Am. Dyestuff Reptr.* **35**, P29–37 (Jan. 14, 1946).

Cotton sheeting was dyed blue with naphthol, vat, diazotized and developed, sulfur, and light-fast direct dyes and exposed to weather in Maine, Georgia, and Alabama. Samples were taken at 2-week intervals up to 14 weeks. At the end of this time the samples exposed in Alabama had lost practically all of their color and from 41 to 65% of their warp strength. Cuprammonium fluidity of these samples varied from 19.2 to 29 rhes and confirmed the results of the warp breaks which showed the order of decreasing resistance to deterioration to be: sulfur-dyed (41% loss), direct-dyed (41% loss), vat-dyed (57% loss), undyed (57% loss), diazotized and developed (60% loss), and naphthol-dyed (65% loss). An accelerated ageing (oven) test reversed this picture in that the sulfur-dyeing showed the most deterioration. K. S. Campbell

Text. Research J. Nov. 1946

Prevention of Crease Marks

Crease marks are serious imperfections. H. E. Wenrich. *Rayon Text. Mo.* **27**, 420–2 (Aug. 1946).

A description is given of several simple devices which can be used to smooth out wrinkles developed as the cloth comes off the loom, thereby preventing creasing of the cloth as it feeds into the roller.

Text. Research J. Nov. 1946 J. F. Keating

Industrial Rayon's Continuous Process

Continuous spinning and processing of viscose rayon. Anon. Excerpt from "The New Fibers" to be published by D. Van Nostrand Co., Inc., New York. *Rayon Text. Mo.* **27**, 418–20 (Aug. 1946).

A description is given of the essential machines used in the continuous spinning process developed by the Industrial Rayon Corporation.

Text. Research J. Nov. 1946 J. F. Keating

Pneumatic Loom

New electropneumatic loom picking device. Anon. *Text. Recorder* **64**, 39–40, 60 (Aug. 1946).

Existing picking motion mechanisms are said to be crude by modern engineering standards. A new device is described which operates the shuttle pneumatically. The picking motion is controlled electrically. A stop motion is also electrically controlled. Higher speeds are possible, e.g., up to 250 picks per min. on a 56-in. reed space loom; larger shuttles and weft packages can be used; and the operation is less noisy. The device can be installed on all nonautomatic power looms.

Text. Research J. Nov. 1946 J. F. Keating

Jute Spinning

Modern jute spinning: bale opening and softening processes. Anon. *Text. Recorder* **64**, 46–7 (Aug. 1946).

A review. J. F. Keating

Text. Research J. Nov. 1946

MISCELLANEOUS

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Fiber-Reinforced Building Material

Plimber utilizing waste materials with aid of synthetic resins. Anon. *Brit. Plastics* **18**, 82–4 (Feb 1946).

Plimber is a plastic composition building material consisting of resin-bonded straw and other fibers, sawdust, sand, etc. It is a useful construction material for floors, inner walls, and furniture. Data on its physical characteristics are given. E. F. Evans

Text. Research J. Nov. 1946

Carboxymethylcellulose

A new plastic for paper makers: Carboxymethylcellulose. William S. Penn. *World's Paper Trade Rev.* **125**, Tech. Sup. 37–9 (May 24, 1946) (through *Bull. Inst. Paper Chem.* **16**, 541 (Aug. 1946)).

The preparation, properties, and uses of carboxymethylcellulose and its derivatives are described. It has been shown to be useful wherever hydrophilic colloids possessing marked suspending, thickening, stabilizing, and film-forming properties are required. Apart from its value to papermakers as greaseproofing, coating, and sizing agents, the product has found application in the textile, paint, food, ceramic, and packaging industries; its possibilities have by no means been exhausted. 11 references.

Text. Research J. Nov. 1946

Textile Applications of DDT

DDT and its textile applications. F. L. Goodall, T. F. Gorton, and J. V. Summersgill. *J. Soc. Dyers and Colourists* **62**, 189–98 (July 1946).

DDT, prepared commercially by condensing chloral with chlorobenzene in the presence of sulfuric acid, contains about 85% of the true active ingredient, the *pp'* compound. The estimation of DDT in textile materials may be successfully accomplished by solvent extraction of the treated material and hydrolysis of the recovered DDT in boiling alcoholic KOH with subsequent determination of the potassium chloride formed during the decomposition $(ClC_6H_4)_2CH \cdot CCl_3 + KOH \rightarrow (ClC_6H_4)_2C = Cl_2 + KCl + H_2O$. (The use of nitrobenzene as an auxiliary in the volumetric analysis of the inorganic chloride has proved of definite advantage.) This estimation of DDT is known as the "hydrolyzable chlorine" method. Although a remarkably stable compound in general, DDT does not withstand such temperatures as encountered in the curing of urea-formaldehyde resins; it is apparently slightly hydrolyzed into chloral and chlorobenzene in this case and in a strong air stream the products are rapidly volatilized. Ordinary textile drying conditions do not affect DDT. Application to textiles may be performed in solvent solutions or in aqueous emulsions; the former requires the dry-cleaning technique while the latter is suitable for ordinary textile machinery; other promising methods of application are in admixture with the tallow component of sizes for cottons and dissolved in the oil applied to wool at various stages of manufacture. In addition to its louseproofing value (some 12,000,000 shirts having been treated for this purpose in England), its insecticidal properties are of value in proofing cellulosic materials against silverfish and termites and woolens against moths and carpet beetles. Fabrics containing 1.0–1.5% DDT will generally lose about 40–60% in one wash; the effectiveness of this compound is so high, however, that the material will often remain protected after a number of washings; dry cleaning of course removes DDT because of its high solvent solubility. With respect to toxicity, there is a very wide margin of safety in the use of DDT; 200 ml. of a saturated kerosene solution is an estimated lethal dose; it is unquestionably as safe as a large number of chemicals in everyday use. K. S. Campbell

Text. Research J. Nov. 1946

Radiant and Convection Heating

Radiant heating. First report of the Joint Research Committee of the Gas Research Board (British). *Brit. Plastics* **18**, 144–8 (Apr. 1946).

Comparison of radiant heating with convection heating for various plastics has shown it to be advantageous for heating transparent polymethyl methacrylate and polystyrene and for processing of coatings of polyvinyl chloride on various textile fabrics but to be unsuitable for preheating Bakelite molding powder pellets. The spectrum of the radiation is important in transparent materials but of little importance for opaque materials. In the latter case, the surface temperature is rapidly raised to a high level allowing much greater rates of heating than by convection but only if the material is not liable to spoil at the surface under the elevated temperature. E. F. Evans

Text. Research J. Nov. 1946

WAR RESEARCH ON TEXTILES *

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Japanese Textiles

Japanese Air Force textiles. (AAF T-2 Tech. Intelligence Review F-IR-83-RE) William A. Corry. PB 33121, June 1946; 14 pp.; microfilm, $1.00—photostat, $1.00 (through *Bib. Sci. and Ind. Reports* **2**, 830 (Sept. 13, 1946)).

Methods of procurement and inspection, responsibility for design, and uses of different raw materials for the construction of various cloths are discussed in this report, based on interviews with Japanese personnel. New production methods for the manufacture of viscose rayon are also discussed. The following appendices contain the information collected: (A) Japanese Air Force textiles; (B) remarks by K. Atsuki, of Tokyo Imperial University; (C) low alkali viscose process, by M. Horio†; (D) special rayon as a substitute for linen, by K. Tanemura; (E) flameproofing viscose rayon with thiourea resin;

* Copies of the original reports abstracted in this section may be obtained from the U. S. Department of Commerce, Office of Technical Services, Washington 25, D.C.

† A paper on this subject by Professor Horio appeared in TEXTILE RESEARCH JOURNAL, October, 1946.

and (F) studies on the improvement of properties of artificial fiber during the war.

Text. Research J. Nov. 1946

U. S. Research

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Deterioration

A study of the probable mechanism of deterioration in processed HBT's and a simple preconditioning treatment to prevent this deterioration. (CWS 43rd Chemical Lab. Co. Tech. Rept. 78.) Howard C. Haas and Harold Rosenthal. PB 27670, July 1945; 35 pp.; microfilm, $1.00—photostat, $3.00 (through *Bib. Sci. and Ind. Reports* **2**, 447 (Aug. 9, 1946)).

Previous work done by the 43rd Chemical Laboratory Company had indicated conclusively that the main factor causing erratic deterioration of processed HBT-impregnated fabrics was the presence of certain materials on the fabrics as received from the manufacturers. This report covers the work that led to the development of a preconditioning treatment to prevent this rapid deterioration. As a result of the work described herein, it was recommended that all HBT materials destined for processing be pretreated with an aqueous 1% Na_2CO_3 solution either by the processing company, Quartermaster laundries, or as a final step by the finisher. The prime requisite is that a distilled-water extract of 5 g. of HBT fabric, diluted to 100 cc., shall have a pH in the range of 9.3 to 9.8 before the garment is processed. It was also recommended that a more rigid specification be made to prevent the presence of oxidizable dyes on fatigue clothing destined for processing. Tables and plotted curves are included.

Text. Research J. Nov. 1946

Flameproofing Treatment

Clothing, HBT, effect of flameproof treatment on: Evaluation of three types of treatment before and after environmental exposure. U. S. Climatic Research Laboratory, Lawrence, Mass. (Rept. 155). PB 34892, Dec. 1945; 131 pp.; microfilm, $3.00—photostat, $9.00 (through *Bib. Sci. and Ind. Reports* **2**, 831 (Sept. 13, 1946)).

This report is a description of the comprehensive examination of 3 types of flameproof agents applied to HBT uniforms. A temporary, a semidurable, and a durable treatment are included. Systematic examinations were made before and after the uniform had been subjected to varying periods of wear, under favorable and unfavorable environmental conditions, and after a series of launderings. Physiological heat load was also determined by the techniques in current use in this laboratory. It is tentatively recommended that type 1 flameproofing treatment be considered unsuitable for military use because of its extreme vulnerability to wear, laundering, sweat, rain, and sea water; that type 3 flameproofing treatment be excluded from further consideration because of its undesirability from a subjective standpoint, its excessive physiological heat load and its unsatisfactory glowproofing properties; and that type 2 flameproofing treatment be considered the most satisfactory of the test treatments, but that its limitations—namely, low initial tensile strength, rapid loss of tensile strength on wear and laundering, and loss of flameproofing on exposure to sea water—be corrected before it is standardized for military use. Appendix I contains list of agenda, and appendix II, experimental data. 84 tables and 10 illustrations are included.

Text. Research J. Nov. 1946

Cottonized Flax and Hemp

The preparation of unretted green or natural and cottonized flax and hemp fibers. Brittain B. Robinson. PB 32263, May 1946; 30 pp.; microfilm, $1.00—photostat, $2.00 (through *Bib. Sci. and Ind. Reports* **2**, 446 (Aug. 9, 1946)).

Text. Research J. Nov. 1946

Shrinkproofing Tests

Report of test of trousers, wool, shrinkproof treatment. (Project T-320; QMB Test 1385.) U. S. Quartermaster Board. PB 28804, Dec. 1944; 23 pp.; microfilm, $1.00—photostat, $2.00 (through *Bib. Sci. and Ind. Reports* **2**, 539 (Aug. 16, 1946)).

Ten pairs of wool serge, 18-oz. trousers and 10 pairs of wool serge, 22-oz., napped-back trousers were subjected to the wear and laundering tests described in this report, in order to compare the relative merits of various shrinkproofing methods. These methods were Hypol, enzyme, Freney-Lipson, wet chlorination, and 2 resin treatments, the details of which are not given. The results of the tests are discussed and shown in tabular form. It was concluded that resin shrinkproofing treatments are the only treatments tested that consistently reduced shrinkage, but both types materially decrease the durability of the trousers. None of the other treatments was satisfactory for improving the shrinkproofing qualities of these trousers and only in the case of the Hypol-treated and possibly in the enzyme-treated is the durability of the trousers not decreased.

Text. Research J. Nov. 1946

Sleeping Bags

Bag, sleeping, wool, experimental, for climatic zones 2 and 3: Thermal insulation and utility. U. S. Climatic Research Laboratory, Lawrence, Mass. (Rept. 87). PB 34878, May 1944; 22 pp.; microfilm, $1.00—photostat, $2.00 (through *Bib. Sci. and Ind. Reports* **2**, 831 (Sept. 13, 1946)).

The purpose of this investigation was to compare the thermal insulation and other physical characteristics of experimental wool batt and wool pile sleeping bags with the wool sleeping bag and the mountain sleeping bag. It was tentatively recommended that: (1) Sleeping bags should be made of down and feathers until the supply of this type of fill is exhausted; (2) wool sleeping bags should be made from

wool batts, wool pile, or wool blanketing, in the descending order of preference; (3) in the new and unlaundered state, the lightweight wool batt bag should be considered as offering adequate protection for climatic zone 2 and an average minimum temperature that does not fall below +10°F; and (4) soldiers should be instructed either to wear their clothing or place it under the sleeping bag or over it, depending upon the position which provides greatest comfort.

Text. Research J. Nov. 1946

Properties of Webbing

Properties of webbing; (revised). U. S. Quartermaster Depot, Jeffersonville, Ind. (Rept. 145). PB 36791, Feb. 1946; 26 pp.; microfilm, $1.00—photostat, $2.00 (through *Bib. Sci. and Ind. Reports* **2**, 896 (Sept. 20, 1946)).

This tabulation of the properties of webbing and substitute webbing was compiled as a result of the conference held at the Engineering Division, J.Q.M.D., Mar. 23–24, 1945, and in accordance with a request from O.Q.M.G. (Proj. 23–45) for data on properties of webbing. Various types of standard and substitute webbings were procured. Test procedure is described, and results are presented in tables and graphs. (One or two pages will not reproduce well.) These data are to be used for the study of webbings in equipage and tentage and in conjunction with a project now being reviewed at the National Academy of Science and Rhode Island State College.

Text. Research J. Nov. 1946

Wool Substitute Fabrics

Preliminary report of study of wool substitute fabrics. (Project S–17.) U. S. Quartermaster Board. PB 32831, July 1943; 30 pp.; microfilm, $1.00—photostat, $2.00 (through *Bib. Sci. and Ind. Reports* **2**, 749 (Sept. 6, 1946)).

The purpose of the test was to determine the relative suitability of the various wool substitute fabrics for use as substitutes for present fabrics manufactured of 100% wool. O.D. overcoats, field jackets, shirts, and gloves were tested. Procedures and test findings are described. It is concluded that present indications are that all of the various substitute fabrics included in this study will prove satisfactory from the standpoint of warmth at temperatures encountered at Camp Lee, Virginia; regular issue fabrics shrink more and are more affected in appearance by laundering than the substitute fabrics; the substitute fabrics tested are as color-fast as the regular issue fabrics; the overcoat fabric containing 15% viscose rayon is more water-absorbent and dries more slowly than other fabrics tested; and repeated laundering shrinks the wool lining of the regular field jacket to such an extent that the jacket is unfit for wear. Shrinkage data are shown in tables and graphs. Photographs of samples show effects of laundering, dry cleaning, and exposure to sun and weather on overcoat fabrics.

Text. Research J. Nov. 1946

German Research

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Continuous Cuprammonium Spinning

Die Dureta Maschine in der Fabrikation der Kupferkunstseide. (The Dureta machine in the production of cuprate silk.) Claasen. PB 19586, Mar. 1945; 24 pp.; microfilm, 50¢—photostat, $2.00 (through *Bib. Sci. and Ind. Reports* **2**, 618 (Aug. 23, 1946)).

With the help of 6 photographs and 1 diagram a machine is described which is intended for the production of hose silk. It is fully automatic so that the thread is not touched by hand from spinning solution to spool. The whole process lasts only 135 secs. The hose prepared from this yarn is homogeneously colored; no deposits of color will show up which formerly were caused by differences between beginning and end of a skein of yarn. Dureta yarns delivered on spools or cones can be applied directly on other machines.

Text. Research J. Nov. 1946

I. G. Farben Dye Register

Fabrikations-register. Farben u. f.h.-produkte. Alphabetischer teil. Fabrikationsprodukte. (3. ausgabe). (Register of products. Dyes and dyeing agents. Alphabetic part. (3rd edition)) (Frames 1–294 of FIAT Microfilm Reel C 21). I. G. Farbenindustrie, A. G. PB 27684, Apr. 1937; 293 pp.; microfilm, $6.00—photostat, $20.00 (through *Bib. Sci. and Ind. Reports* **2**, 547 (Aug. 23, 1946)).

This register is in 2 parts. The first part lists dyes and agents according to a "Hollerith" punch and number, the particular plant of I. G. where the material is produced, its purity and concentration, and the page in the I. G. System-register, where it may be located. In the latter part of the volume is a series of voided materials. In German. If this document is desired in microfilm form, it should be ordered as PB 4681.

Text. Research J. Nov. 1946

Fiber Structure

Feinstruktur und textile eigenschaften. (Fine structure and textile properties.) (ALSOS Mission, RFR 507 23.) O. Kratky. PB 19450, n.d.; 6 pp.; microfilm, 50¢—photostat, $1.00 (through *Bib. Sci. and Ind. Reports* **2**, 618 (Aug. 23, 1946)).

Six selected synthetic fibers were submitted to the following radiographic measurements: (1) determination of the orientation of crystallites, (2) determination of the quantities of the crystalline portion by measurement of the interference intensity, and (3) determination of the course of the small angle deviation. The results of these measurements are tabulated together with the tested values for tensile strength, extension, swelling, degree of polymerization, loop strength, and knob strength. In German.

Text. Research J. Nov. 1946

Report on textile research at the Textile Chemical Institute of the Mulhouse-Alsace Technical College. Herbert F. Schiefer and Richard T. Kropf. PB 33103, 1945; 22 pp.; microfilm, $1.00—photostat, $2.00 (through *Bib. Sci. and Ind. Reports* **2**, 539 (Aug. 16, 1946)).

This report, published in TEXTILE RESEARCH JOURNAL, Sept. 1946, consists of a translation of an unpublished manuscript by Egon Elöd and H. G. Fröhlich entitled "The Influence of Fiber Structure of Rayon on Swelling and Radial Density," and a list of papers published by Prof. Egon Elöd and his staff since 1941 on the structure, dyeing, and chemistry of protein, cellulose, and nylon. Graphs show swelling and density of fibers.

Text. Research J. Nov. 1946

Finishing Machinery

Textile finishing machinery for cotton and rayon piece goods; and Jacquard machines for looms weaving figured cloth, by H. Hardaker. (BIOS Final Rept. 106, Item 31.) H. Kay. PB 28750, Oct. 1945; 22 pp.; microfilm, $1.00—photostat, $2.00 (through *Bib. Sci. and Ind. Reports* **2**, 618 (Aug. 23, 1946)).

These makers of textile machinery in the British Zone do not manufacture a complete range of necessary machines, confining themselves principally to calenders, shearing machines, Palmer finishing machines, pin tenters and making-up machinery. The only new developments since 1938 are the spray damping machine and the spirally woven cloth for making cotton bowls, which was introduced about 1936, both at Briem. Sketches illustrating these are included. None of the targets had close connections with dyers or finishers or had research departments of their own. Judging from the machine tools seen in the works, their products seem to be on a par with English makes of similar machines, and generally the English have nothing much to learn from them. The second part of the report covers visits to Mertens and Frowein Webstuhl Fabrik at Neviges Elberfeld; Jean Gusken at Dulken; and Carl Zangs, A. G., at Krefeld. The first two do not make Jacquard machines. A diagram is attached showing cylinder motion of a double-cylinder Jacquard machine suitable for endless paper cards made by Carl Zangs. Machines made by them are listed. The two not made in England are the Verdol coarse pitch machine, two cylinders on one side, and the card-cutting transposing machine.

Text. Research J. Nov. 1946

Loom-Making Machinery

Loom making in Germany; and textile machinery accessories, by R. S. Fearnehough. (BIOS Final Rept. 455, Item 31.) O. Porter. PB 28749, Oct. 1945; 19 pp.; microfilm, $1.00—photostat, $2.00 (through *Bib. Sci. and Ind. Reports* **2**, 619 (Aug. 23, 1946)).

The object of the first part of this investigation was to obtain detailed information of any developments in the manufacture of looms and preparing machinery not readily available in England. Many of the largest and most important loom makers in Germany are situated in Saxony in the Russian Zone. This report is confined to 7 firms in the British and American Zones of Occupation. Compared with English standards, many of the firms had obsolete plants with 2 exceptions, all had badly laid out works. At Rhein Kunstseide, A. G., Krefeld, a low-built dobby loom, 4 box pick and pick motion made by Carl Zangs and at J. Wulfing & Sohn, Dahlerau near Lennep, looms made by Louis Schonherr in Chemnitz, and the Gessner decatizing machine were recommended for evacuation. Photograph and descriptive matter for low-built silk loom manufactured by Carl Zangs are included, together with photographs of carpet looms manufactured by Mertens & Frewein G.m.b.H., a warping machine with creel for silk found at Jean Gusken, and a chiffon velvet loom with knife cutting motion and a self wire loom found at Felix Tonnar. The second part of the report covers 4 firms for manufacture of spiral cutters, machine knives and blades, etc.

Text. Research J. Nov. 1946

Spinning Rayon Staple

The Zellwolle Lehrspinnerei: The German organization for research on spinning of rayon staple; its objectives, methods, and equipment. (Textile Series Rept. 12.) U. S. Quartermaster Corps. Military Planning Division. PB 31869, May 1946; 99 pp.; microfilm, $2.00—photostat, $7.00 (through *Bib. Sci. and Ind. Reports* **2**, 663 (Aug. 30, 1946)).

This organization was established in 1938 in Denkendorf in South Germany. Its plant of about 7,000 spindles was the central testing and research institution for the German rayon staple fiber spinning industry. It developed and tested techniques and equipment and prepared reports for circulation to the industry. This report contains a general outline of the structure of the organization, a list of its active research projects, a sample of a typical research project record, lists of testing and machine equipment, and plant and machinery layouts. This report consists in principal part of documents collected by the Textile Team. Also included is a report on textile machinery at the Zellwolle Lehrspinnerei, by J. L. Truslow and Robert M. Jones, describing individual machines and processes and including a list of the technical books of the institution, translated by Dr. Julian F. Smith (T.I.I.C.). Photographs and sketches accompany the report. The foreword states that this is the kind of research organization which has long been talked about in this country.

Text. Research J. Nov. 1946

PATENTS

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Alginic Acid Compounds

Production of alginic acid compounds. George Eric Cunningham, Norman Henry Chamber-

lain, and John Bamber Speakman (to Cefoil Ltd.). U. S. 2,403,707 (July 9, 1946).

Alginic acid is very unreactive in nonaqueous systems. Such reactions as acetylation which require nonaqueous media are unsuccessful on alginic acid. This invention involves first swelling the alginic acid with water and then removing the water with glacial acetic acid, followed by treatment with the acetylating mixture. A 95% yield of a product containing 33 combined acetyl is obtained. A. R. Martin

Text. Research J. Nov. 1946

Elastic Cotton Fabric

Method of making cotton fabrics with differential elastic properties. Charles F. Goldthwait (to the United States of America, as represented by the Secretary of Agriculture). U. S. 2,404,837 (July 30, 1946).

The fabric is treated with caustic soda which swells and shrinks it, the caustic is removed, and the fabric is dried while under tension in one direction only. The effect is to produce a crimp in the yarns dried without tension, *e.g.*, the warp yarns, thereby yielding a fabric with a high degree of warpwise elasticity. A. R. Martin

Text. Research J. Nov. 1946

Novelty Knitted Fabric

Knitted fabric. Edwin Wildt, Henry Harold Holmes, and John Cyril Herbert Hurd (to Wildt and Company Ltd.). U. S. 2,403,201 (July 2, 1946).

The fabric contains a fancy stitch combination consisting of a lap or wrap or embroidery loop or stitch effect and a transferred loop or stitch effect directly associated. The novel feature is that the 2 associated loops are contained in the same needle wale. A. R. Martin

Text. Research J. Nov. 1946

Improving Adhesion of Resins to Glass

Treatment of glass fibers. Kenneth J. Miller (to Owens-Corning Fiberglas Corp.). U. S. 2,403,872 (July 9, 1946).

The glass fabric is treated with equal parts of resorcinol and formaldehyde and dried at a low temperature. The treated glass fibers are then impregnated with resin solutions and the resin is cured. Improved adhesion between resin and glass results, thereby enhancing the physical properties of the resulting laminate. A. R. Martin

Text. Research J. Nov. 1946

Protein Fibers

Production of fibers from proteins. Frederick K. Watson (to E. I. du Pont de Nemours & Co.). U. S. 2,403,251 (July 2, 1946).

Globular proteins are solubilized by means of 8% sodium dodecyl sulfate to produce a spinning solution having a pH of 5.8 and being quite stable as compared to alkaline spinning solutions. A. R. Martin

Text. Research J. Nov. 1946

Improved Lickerin Roll for Cards

Carding engine. John Locke (to British Cotton Industry Research Assn.). U. S. 2,403,384 (July 2, 1946).

A device is disclosed which is claimed to give better cleaning of the cotton when used in conjunction with the lickerin roll. A. R. Martin

Text. Research J. Nov. 1946

Rope-Piling Apparatus

Textile rope-stacking apparatus. Sydney Steel (to E. I. du Pont de Nemours & Co.). U. S. 2,403,311 (July 2, 1946).

Reverse helical grooves are cut into an elliptical advancing roller.

Text. Research J. Nov. 1946 A. R. Martin

Sizing Apparatus for Yarns

Process and apparatus for sizing yarns. James Andrew Clark (to Sylvania Industrial Corp.). U. S. 2,402,653 (June 25, 1946).

A machine is described for the sizing of yarns with coagulable substances, such as alkali-soluble cellulose derivatives, which has grooved rollers to keep the individual yarns separate. A. R. Martin

Text. Research J. Nov. 1946

Vinyl Coating Compound

Coated fabric. Ernest A. Rodman (to E. I. du Pont de Nemours & Co.). U. S. 2,404,313 (July 16, 1946).

The azelaic diester of monobutyl ether of ethylene glycol is disclosed as being a plasticizer for vinyl copolymers which yields coating compositions that maintain good flexibility at low temperatures and do not become tacky at room temperature. A. R. Martin

Text. Research J. Nov. 1946

Prevention of Edge Curling

Method of treating textile material to prevent edge curling. Joseph F. Gifford (to United Merchants & Manufacturers, Inc.). U. S. 2,402,621 (June 25, 1946).

The curled fabric is uncurled by means of air streams from jets. While the fabric is maintained in this uncurled position a suitable setting treatment is applied. This latter may be heat, pressure, steam, together with a setting agent, but there is no discussion regarding this. This patent discloses only the method of handling the fabric and applying a setting agent.

Text. Research J. Nov. 1946 A. R. Martin

Prevention of Gas Fading

Inhibition of acid fading on cellulose acetate with melamine resin. Henry Charles Olpin and Sydney Alfred Gibson (to British Celanese Ltd.). U. S. 2,403,019 (July 2, 1946).

It is disclosed that condensation products of certain nitrogen-containing compounds with formaldehyde will inhibit gas fading of acetate rayon dyed with members of the amino-anthraquinone series. Melamine resin is particularly suitable. Presumably, the acidic components of the gas combine with the basic nitrogen of resin rather than that of the dye. A. R. Martin

Text. Research J. Nov. 1946